HOW COMMON THINGS ARE MADE

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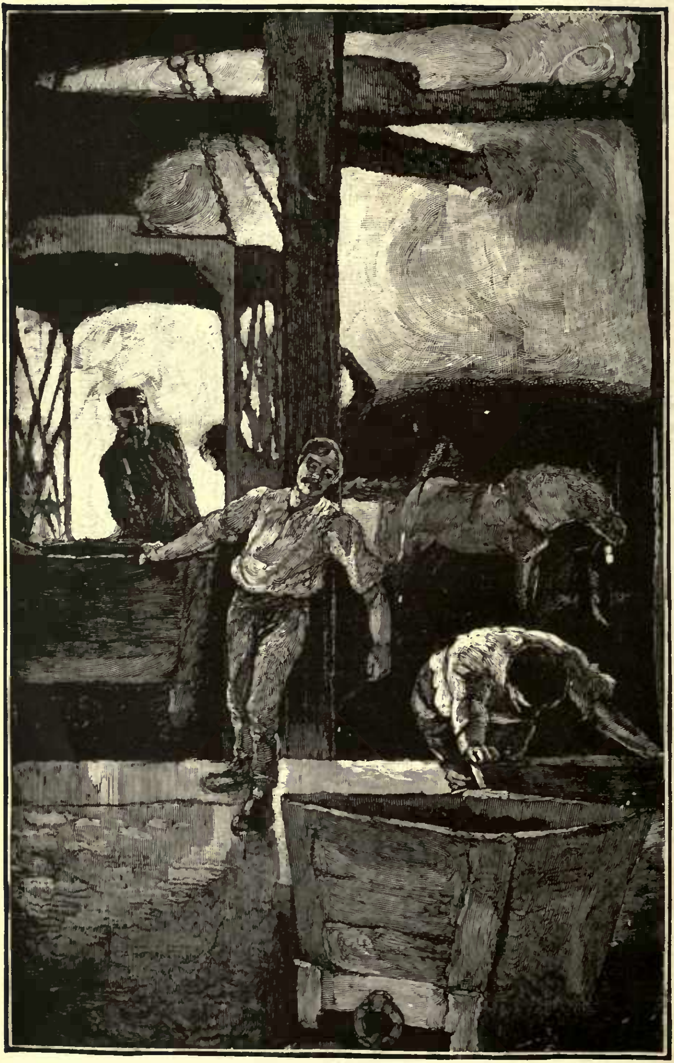

A Peep into a Coal Mine.

How Common Things are Made.] [*Frontispiece.*

How Common Things are Made.

By

W. A. ATKINSON.

John F. Shaw & Co.,

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HOW POTS ARE MADE.

DID you ever see a potter at work? It is really a most interesting sight. He sits at a little round table, scarcely larger than a plate, which is spinning like a top. He throws a little lump of wet clay in the centre of it, and rounds the lump with the palms of his hands. Then he sticks his thumbs into the middle of it, as it is whirling round, hollows out the centre, and draws up the sides of the clay with his fingers. A cup seems to grow from the table as if by magic, yet it is all done by the skill of the potter's hands. In a few seconds it is shaped, and then it is measured in order to make sure that it is the same size as the other cups which are to make up the tea-set. If the potter is satisfied with it, he stops the spinning of his table, or "wheel," as it is usually called, and cuts away the cup from the top of it with a wire in place of a knife. A boy takes the cup away, and the potter starts his wheel once more, and fashions

another cup upon it. So he goes on all day long, making cup after cup.

The cup, as it leaves the potter's wheel, has no handle upon it. That is made separately, and put on afterwards. The handles are made by pressing the clay into moulds. If you took a handle broken off from a cup, pressed it between two pieces of soft clay, and afterwards separated these pieces again, you would have upon each the impression ot the handle. If you made each of these pieces of clay hard, by baking them, for instance, you would have two halves of a mould, with which you could make other handles, by pressing new soft clay between them, and taking it out again when it had received the impression of the mould. It is in this way that the potter makes his handles, only his moulds are made of plaster. When the handle is taken out, it is fastened on to the cup by dipping the ends into very watery clay, called "slip," and applying them to the cup. The cup and the handle have both been dried, and the dry clay absorbs the water of the slip so quickly, that the handle sticks in a minute or two, and the cup may be lifted by it.

The cup is now its proper shape, but it is only clay still, and if you were to use it, it would lose its shape, and become as it was

before the potter made it. To make it hard and fit for use, it must be baked. The baking is done in an oven shaped like a bee-hive and as large as a room. This oven, with everything in it, is made white-hot by a number of fires placed around it, and the heating and cooling of it will occupy altogether three or four days. The cups, saucers, plates, and other articles which are being baked are enclosed in fire-clay boxes to protect them from dust, soot, and smoke. When the cup comes out of the furnace, it is no longer clay, but pot or porcelain, according to the materials of which it was made.

If you look at the teacups which you use, you will find that they are bright and glossy. Our teacup which has just come from the oven is not like that. It is dull and grey. In order to be made like those in use it must have a glaze put on it. Now a glaze is really a glass put thinly over the whole of the cup or other article which is glazed. As glass is hard, smooth, and glossy, it gives these qualities to the pottery which it covers. It is put on in a rather roundabout way. The potter knows that there are certain kinds of earth or stone which, when heated to a great temperature, turn to glass. He contrives to grind them very small and mix them with water. Into this liquid he dips the cup

which is to be glazed. The baked pot sucks up the water, and the little particles of glazing-stone are left sticking all over it. The cup is once more placed in an oven and baked. The great heat melts the particles of stone into glaze, which runs all over the surface of the cup, and, when the cup is allowed to cool, sets like glass.

This is the way in which plain cups are made, and the process is nearly the same for common plates, saucers, and basins. But those which are ornamented in any way give much more trouble. As a rule ornamented objects are moulded in pieces, and afterwards stuck together by "slip," as the handles are made and fastened on to the cup. They may have to be baked in the oven, not once only, but many times. So, too, those which are painted or gilded have to be baked many times, because the colours or the gold are put on as a liquid, like the glaze, and are fixed by heating in the oven. These colours and gilt, as the painter puts them on, are not at all like what they will be when the article is burnt.

One change which a piece of pottery undergoes in the oven is very striking. It shrinks up, and comes out much smaller than it was when put in. The potter knows all about this, and he makes everything larger than it

is required to be when finished. Great care has to be taken to prevent each thing shrinking in a crooked way. Still this does sometimes take place, and then the object is spoiled, and has to be thrown away or ground up and made into clay again.

There are many other processes used in the great works where pottery and porcelain are made, which you would, no doubt, like to have described to you. But it would, perhaps, be difficult to make them quite plain to you. If you understand so much as this you will have a good idea of the way in which the potter does his work, and you will be, I am sure, sufficiently interested to take the first opportunity of peeping into one of the works where such useful and beautiful things are made at the cost of so much skill and patience.

HOW ROPES ARE MADE.

ROPES and twine of all sizes are made of hemp. This hemp is nothing but the fibres of the bark of a plant, which is also called the hemp. The plant which is a kind of nettle, is cultivated in fields for the sake of its bark. When full-grown it is plucked up by the roots, steeped in water for a time, and spread to dry in the sun. When thoroughly dry it is broken by beating it, and the broken wood is stripped away from the bark by means of wooden blades. After much labour has been spent upon it, the bark of the hemp-plant is changed into long, coarse threads, and is ready for the rope-maker.

Rope-making, like brick-making, is one of those industries which is still sometimes carried on in the open-air, or under an open shed. The ground set apart for rope-makng is called a rope-walk, because the rope-maker walks to and fro while he is at work. The rope-walk is generally narrow, but it is al-

ways rather long, being sometimes four hundred yards or more in length. Some walks have only a small shed at one end, while others are covered throughout their length, so that the rope-makers and the ropes may be protected from the wet. Those which are open are often sheltered by rows of trees, or by high edges down each side, and are like a long, straight lane, sheltered by trees or hedges.

At one end of the rope-walk, under the cover of the shed, there is a spinning wheel. This is a large wheel, set in a kind of frame to support it. In the same frame are several smaller wheels, about the size of bobbins, so arranged that when the large wheel is turned round, they also are made to turn by it, but at a very much greater speed. Upon the end of each little bobbin, or *whirl*, as it is sometimes called, there is a hook which turns with the bobbin. The spinning wheel is so arranged that all the hooks point down the rope-walk.

Two men must work together to make each length of cord or twine. One sits at the spinning-wheel, and turns it by means of a handle, while the other forms the rope. The latter has a bundle of hemp wrapped loosely round his waist, so that he may easily draw out a few threads at a time. Pulling a few

out with his fingers, he twists them together and makes a short length of string without tearing the threads away from the bundle. Before his companion begins to turn the spinning-wheel, he ties the end of this short piece of string to the hook of one of the whirls.

When it is made fast, the spinner at the wheel turns the handle, and the little whirl and its hook spin round rapidly, and twist the little piece of string very tightly. Meanwhile the rope-maker with the hemp round his waist begins to walk backward along the rope-walk. As he goes, the cord, which is already twisted and fastened to the hook, pulls out more hemp from the bundle, and twists it into a longer and longer cord. The rope-maker holds up the cord with his left hand, which is protected by a piece of cloth, and helps to draw out the hemp from the bundle with his right hand. He is very careful to draw it out evenly, so that no part of the cord may receive more hemp than another, and thus become thicker; and as the threads of hemp pass through his left hand, he presses them straight and even, so that they twist into a neat cord.

The rope-maker continues to walk backwards, adding more hemp to the string, until he reaches the other end of the rope-walk,

when he calls to the spinner to stop the wheel. The spinner or another man takes the twisted cord from its hook, and either lays it aside or winds it on a reel. In winding, he wraps the end of the cord round the reel, and keeps on turning the reel, as the rope-maker, who has hold of the other end of the cord, walks towards him. The latter is careful to keep the cord tight, so that it may not untwist. When it is all wound on the reel, the rope-maker cuts off the string from his waist, and begins again at the spinning-wheel to make another length like the first. If the cord is not wound on a reel, it is laid aside upon hooks attached to posts by the side of the rope-walk ; and other cords are added as they are made, until there is a large bundle or skein. In many rope-walks the posts are shaped like the letter T, and long nails are driven into the top of them, and left standing up like the teeth of a rake. As the lengths of cord are made, they are laid aside on the top of these posts, each cord between a different pair of nails, in order to keep them separate.

A thick cord is made of smaller cords twisted together, and ropes of all sizes, even to the great ones used by ships, are made from smaller ones in the same way. But there are one or two little things which need

to be explained in the twisting of small cords together in order to make large ones, so we will watch the workman carry his rope-making a little further. Suppose that he has made three strings all alike, and laid them aside upon the tops of his T-shaped posts. He wishes now to twist these three strings together, in order to make a thicker cord. It is easy to see that if he fastened them all to one hook of his spinning-wheel, he could twist them together in very nearly the same way that he twists the hemp threads together. But he does not do this. He fastens each string to a separate hook of the spinning-wheel, while at the other end they are all joined to one hook, which is loosely attached to a sort of sledge, in such a way that it may turn round. As the spinning-wheel goes round, each string is twisted by its own hook, and it is, at first sight, rather difficult to see how they can all be twisted round each other in this way. But each string as it goes round is turning the hook on the sledge at the other end of the rope-walk; and as all the strings are attached to this hook, it, as it goes round, twists them all together. As the strings twist round each other they shorten, and the sledge is pulled towards the spinning-wheel. It is weighted by the rope-maker so that it may not be drawn up too

quickly, and so that the strings may be twisted tightly.

But, besides being twisted tightly, the cord must be twisted evenly. If there were nothing between the sledge and the spinning-wheel, the cord might twist tightly in one place and be rather loose in another. The rope-maker prevents this by means of a piece of wood, which he calls a *top*. It is rather like a large bottle-cork in shape, but it has three grooves cut along its sides. The rope-maker, starting at the sledge end of the walk, puts his top between the strings, allowing each string to lie in one groove. As the spinner turns his wheel, the rope-maker walks slowly towards him, drawing his top along as he goes. In front of him each of the strings is separated by the top, and is twisting alone; behind the top the strings are all joined to one hook, and are twisting together. The rope-maker, by moving his top quickly or slowly, can regulate the twisting of the rope, and make it even from end to end.

This is the simplest way of making twine, cords, and ropes. Nearly every rope-walk has some sort of rude machine for making the work easier, or for performing it more quickly. But I have purposely described the simplest way of making ropes, because

it shows us all that is really necessary for the work. If you understand this, you will soon understand any machine which helps in the work ; for machines only copy the work that is done by hand.

HOW LIME IS MADE.

IN many parts of England, especially in those districts where we find steep, rocky cliffs and pretty ravines, as at Matlock in Derbyshire, limestone is very abundant. Usually this stone is grey, or white, and hard. But it varies a great deal in appearance, and may be red or yellow in colour, and soft instead of hard. Marble and chalk are both different kinds of limestone, and marble is, as you know, very hard, while chalk is quite soft. Perhaps you will ask how we are to know limestone from other kinds of stone, if it varies so much in appearance. Limestone is the kind of stone from which lime is made; and when I have told you how this is done, you will see that there is one easy way of finding out whether a piece of stone is limestone or not.

Not very far from where I live, there is a rocky cliff by the side of a river. This cliff is a limestone one, and a good deal of lime is made there. The stone is rather

soft, and in bygone days many people have dug themselves little caves in the rock, and used them as sheds and store-rooms. One man even made himself a house in the rock. He commenced by hollowing a cave in the foot of the cliff, after which he began to chip down the roof of the cave, until after years of labour, he cut his way out at the top of the cliff. His house was then like a cave with a very wide chimney. He put a number of wooden floors in the chimney, and so divided it into rooms one above another. These rooms he enlarged, and made stairs from one to another. He was a clever man, and he even made use of the stone which he had cut away. He chipped the large pieces into square building stones. The small pieces he carried out, and burned them in a fire of wood. And when the fire was burned out, instead of a heap of stones, he had a heap of lime. With the lime he made mortar, and, taking the building stones which he had already cut, he built up the front of his cave, with the exception of a door and windows, and so made himself a very curious house in the rock, which may be seen to this day.

When this man made his lime by burning the limestone, he only did what he had seen the lime-makers do. But the man who

makes lime in large quantities for sale burns his limestone in a specially made fireplace, called a limekiln. The limekiln is a large hole in the ground by the side of the quarry from which the limestone is taken. The top of the kiln is level with the surface of the ground round the quarry, and at the bottom of the quarry there is an arched opening leading to the bottom of the kiln. Imagine that the head of a very large clay pipe is buried in the ground by the side of a limestone quarry. The bowl of the pipe represents the kiln, while the archway leading to it from the bottom of the quarry is placed just where the stem would be joined to the bowl of the pipe. The kiln and the archway are cut out of the rock, or, if the ground is soft, they are built of stones. Between the top of the arch and the bottom of the kiln there is a grating of iron bars.

The workmen in the quarry knock down large blocks of limestone, and break them up into small pieces. These are loaded into waggons, and run up to the top of the quarry and round to the edge of the kiln. A little of the stone is thrown upon the bars at the bottom of the kiln, and then a layer of wood or coal is laid upon the stone. On the top of this layer another row of stone is laid, then another row of wood, and so on until

the kiln is filled. The last layer is made of wood or coal. When the kiln is finished, the wood or coal is set on fire, and very soon the kiln is red hot. When the fire has burned itself out, there is nothing left but lime. The workmen then run a little waggon into the arch at the bottom, take out an iron bar or two, and let the lime fall into the waggon until it is loaded, when they draw it away, and put another in its place. When the kiln is empty, they are ready to begin again.

How long the fire will burn in the kiln depends upon the amount of wood or coal which the limeburner puts in. He knows that some limestones require more burning or roasting than others. Some soft ones like chalk may be burned in a day, while hard ones may take two days or more. While the lime is burning a blue smoke rises from the kiln. A poisonous gas rises with it, and it is dangerous for any one to remain near the mouth of the kiln for any length of time. Poor men, who have gone to sleep near limekilns in order to be warm, have often been suffocated.

The lime as it comes from the kiln is known as quicklime. The builder uses it for making mortar. He first of all "slakes" it by pouring water upon it. This makes

it steam and grow quite hot. After a time sand is added to it, and more water is mixed with it, until it forms the soft mortar with which the bricks are cemented together into walls.

Only limestone will turn to lime when it is burnt in a fire. If we wish to know whether a piece of stone is limestone or not, we may generally tell by throwing it upon the fire. If it turns into a soft, white, crumbling lump, we may be sure that it is limestone. There are other ways of knowing limestone, but I think you will remember this one best. In some Eastern countries there are ruins of temples, which were destroyed by fire many centuries ago. The traveller who visits them often finds that the pillars and sculptured stones, which were once made of beautiful marble, have been burnt to lime by the fire which destroyed the palace.

HOW BOTTLES ARE MADE.

BEFORE a workman can make a bottle, he must have glass. Now glass is not like the clay which the potter uses. It cannot be dug up almost ready for use, but it has to be manufactured out of several different things. We could make glass by mixing together sand, lime, and the ashes of burnt wood, and afterwards heating them in a very hot fire. After a time they would melt and run together; and if we then took them out of the fire and allowed them to cool, we should find that we had got a piece of glass.

The ashes of burnt wood contain a substance known as potash, and it is in order to use this potash that we add the wood ashes to the sand and the lime. Glass-manufacturers use a great many substances for making glass of various qualities, but only these three are necessary. The others are added to make the glass white, or to make it melt more easily, or perhaps because they are cheaper than some of the things

we have named. Soda, for instance, is very often used in the place of potash.

When the manufacturer has mixed his sand, lime, soda, and other materials in their proper quantities, he puts them into baked clay pots, and these he places in a very hot furnace. The pots must neither crack nor melt with the heat, and so they have to be made of the very best clay for resisting heat, which is found at Stourbridge in Worcestershire, and the potter uses every care to make them as well as he can. It takes a day or two to make one in soft clay, and five or six months to dry it and bake it ready for use. All this trouble makes these pots very costly.

The glass-pots, filled with their sand and other materials, are put into a brick furnace, where the flames of a great fire may blaze all round them. Opposite each glass-pot there is an arched opening in the side of the furnace, and this is nearly built up after the glass-pot is put in it. A little opening is left, however, through which each glass-pot may be watched, and attended to if required. It takes about sixteen hours for the materials in the glass-pots to melt, and turn into glass.

Cold glass, as you know, is very hard and very brittle. We cannot bend it or shape

it, or work it in any way, except by cutting it with a diamond. But when glass is made very hot, it becomes soft and pliable, and by and by, if the heat is great enough, melts altogether. When it is in the soft state, it may be bent and twisted into almost any shape, just as hot iron can; and when it is completely melted, it will flow like water, and may be cast in moulds like molten iron. All the glass things which we see around us, bottles, vases, window-panes, and looking-glasses, have been made when the glass was soft or melted.

The strangest of all these shapes is the bottle, because it is hollow, and has only a very narrow neck opening into it. Let me tell you how one of these is made, for it is the strangest part of glass-making. The man who makes glass bottles is called a glass-blower, because he blows them to that shape with his breath. He has a long tube or blow-pipe, with a mouthpiece at one end, while the other widens out a little, like a small bell. The blow-pipe is, in fact, rather like the long horn which the drivers of coaches and char-a-bancs sometimes play upon, but it is longer, and the bell end is much smaller. The glass-blower stands on a small platform in front of one of the holes in the furnace. When the glass in the glass-

pot within the furnace is quite melted and ready for use, the glass-blower puts the broad end of his blow-pipe through the hole in the furnace, and dips it into the glass. As he draws it out, a little ball of hot, soft glass sticks to the end of the blowpipe. The blower lets it hang over the edge of the platform on which he stands, and blows through the tube. A round glass bubble forms on the end of the blow-pipe. This bubble the glass-blower can shape almost as he likes. If he wants it long, he swings his long blow-pipe like a tolling bell, and the weight of the glass itself draws it out long and narrow. If he wants to make the bubble wide, he flattens it out by beating it like a rammer on the platform. If he wants to round it in any way, he rolls the bubble on a table, just as he might trundle a mop on it. If he wants the bubble larger, he blows again through the blow-pipe. In this way he can get almost any rounded shape that he may wish. If the glass grows cold and stiff, he puts it through the hole into the furnace again, and holds it for a few moments on the end of his blow-pipe in the middle of the flames.

There is one thing, however, which the glass-blower cannot do by simply blowing. He cannot blow a glass which has straight

sides or square corners, as most bottles have, any more than you or I can blow a square soap-bubble. In order to get the corners on his bottle, he must make use of a hollow, wooden mould. This mould is shaped something like a bottle, and is split in two down the middle, both halves being fastened together by hinges on one side. Imagine a wooden bottle made to open like a book, and you will understand better what this mould is like. The hollow inside, when the mould is closed, is just the shape of the bottle, which the blower wishes to make.

When the glass-blower has blown a little bubble of glass, a boy, who is helping him, opens the mould, and the man puts into it the end of his blowpipe, with the bubble attached. The boy closes the mould, and the blower continues to blow. The bubble grows, until it fills every corner of the hollow in the mould. When that is accomplished, the boy opens the mould again, and the blower draws out his glass bubble, which is shaped exactly like the hollow in the mould. The bottle is made. The blower cuts it off his blowpipe, and the boy carries it away to an oven, where it will be allowed to cool slowly, so that it may not break. When it is cold, it is ready for use.

I have not space to tell you how other

glass objects are made, though I feel sure you would be interested in learning how the glass-maker cuts and bends the glass into all kinds of beautiful shapes, how he sticks on handles and feet, and how he rolls out the large sheets of glass of which mirrors are made. I should like to tell you more, but for the present I must be content if I have made you understand how the glass-blower blows those bubbles of glass with straight sides and square corners which we call bottles.

HOW IRON IS MADE.

I HAVE already told you how lime is made from limestone. Iron is made in a very similar way from another kind of stone, called ironstone or iron ore. There are many kinds of ironstone, and it is not always easy to tell which is an ironstone and which is not. Many of them are red; but others are grey, and almost like building stones. Some are soft, and look like red chalk, while others are almost as hard as the iron itself. Whatever they look like, they are made of iron, combined with other things which the ironmaker regards as impurities. These impurities are of many kinds, and some are got rid of without much difficulty, while others, like sulphur, are so tiresome that they spoil the iron entirely, and prevent the ironmaker from using the ores which contain them.

If we took a piece of ironstone, and tried to melt it in a vessel over a fire, we should find that we could not change it in that way. If we threw it into the midst of a hot fire,

and tried to roast it, we should probably get nothing but a drossy stone. But if we had a very clean, bright fire, such as a charcoal fire, and if our ore chanced to be a very good piece, we might perhaps find, when the fire burned out, that there was a little lump of iron in the ashes. This would show us that iron can be obtained from ironstone in very much the same way that lime is got from limestone.

Before I tell you how iron is made in England, let me describe how it is made in some parts of Africa by the natives. They dig a little hole in the ground, and light a fire at the bottom of it. Upon the top of the fire they lay first a row of charcoal, then a row of ironstone broken very small, then another row of charcoal, and above that another row of ironstone, and so on. They blow the fire with bellows, and make it burn as fiercely as possible. As the fire burns away, they throw on new supplies of charcoal and ore with their hands. After a time they let the fire burn out, and they find at the bottom of the hole a piece of iron about the size of a hen's egg, which they can make into a spearhead or other useful weapon.

In England thousands of tons of iron are used every year. This would not be possible if we did not know how to make great quan-

tities of iron at one operation. In order to do this, Englishmen construct large blast-furnaces, which will hold many tons of iron-stone and charcoal or coke, and make several tons of iron in a day. The blast-furnace is like a limekiln built above the ground. The outside of it looks like a tower of stone or iron, while the hollow inside is shaped rather like an egg, with its broad end at the bottom and its narrow end open to the sky. At the bottom of this hollow a fire is lighted, and fuel and ironstone are loaded upon the top of it through the open mouth of the furnace. All this, as you will remember, is very like what goes on when limestone is being burned in a limekiln.

The natives of Africa blow their little fires with bellows; and in bygone days Englishmen used to blow their blast-furnaces with bellows. But now they force great quantities of air into the furnace by means of steam-engines and a machine which pumps the air, as it were, through pipes which open into the furnace. This air is called a blast, and the blast-furnace takes its name from it.

The fuel which is used in the English blast-furnace is coke, or, in other words, the cinders of coal. These are found to make a cleaner fire than coal itself would do. The blast causes the coke to burn with an intense

heat, but, unfortunately, the ironstone used in England is not very pure, and even this great heat is not sufficient to melt the iron out of it. But those who make iron have discovered that, if lime be put into the furnace, along with the coke and ironstone, it will help the fire, and acting together the lime and the fire will melt out the iron. So the ironmakers put in loads of limestone along with the loads of ironstone and coke. The fire roasts the limestone, and turns it into lime. The heat is so great that the ironstone and the lime melt at the same time, and the lime and the impurities of the ironstone run together, and form a kind of melted glass, called slag. The melted iron is left.

Now I wish to show you very clearly, if I can, how the melted slag and the melted iron are separated. If I took a glass jar containing some yellow oil, and poured clean water on the top of it, the water would soon fall to the bottom of the jar, while the oil floated above it, because the oil is lighter than the water. If I now poured a little treacle into the jar, it would fall at once to the bottom, because it is heavier than either the oil or the water. Looking at the side of the jar, I should see the golden treacle at the bottom, the clear water in the middle, and the yellow oil at the top. If I made a hole in the

bottom of the jar, the treacle would run out first; if I made a hole in the side of the jar opposite the water, the water would run out first; while if I emptied the jar by its mouth, the oil would come out first.

Of all the materials in the blast-furnace, the melted iron is the heaviest, and falls to the bottom. The melted slag is next heaviest, and falls until it reaches the iron, and floats on the top of it. There is a hole quite at the bottom of the furnace, and there is another one a little higher up. The workmen close the lower opening with soft clay, which is soon baked into hard brick by the heat inside the furnace. The higher hole opens upwards, somewhat like the spout of a coffee-pot broken off short and close to the jug. This hole is always open, but, as it opens upwards, no coke or ironstone can fall out through it. As the slag melts and becomes like water, it rises up in the furnace, and by and by flows out of the hole, just as water, poured into a coffee-pot with a broken spout, would run out of the spout when it reached a certain height. The slag runs away like a little red-hot stream into an iron box, where it slowly cools.

As the iron melts and rises in the furnace, it, too, would run out of the slag-hole after a time; but the workmen are watching, and

before it rises so high they break open the lower opening with iron bars, and let the iron run out by that way. It gushes out like fiery water, and it is allowed to run into a number of little gutters made of sand, in which it is left to cool. When the iron has run out of the furnace, the workmen stop up the hole again with soft clay, to prevent any slag coming out after the iron.

Even after all this trouble, the iron is not very pure, not quite so good, in fact, as the little lumps made by the African savages. It cannot be hammered or bent without breaking. It is called *pig-iron*, and a little more labour will make it into the *cast-iron* of which stoves, ovens, and fire-places are made. But much work must be spent upon it before it is fit to be made into boilers for engines, gasometers, ships like our iron-clads, and great iron bridges like the Forth Bridge.

HOW BRICKS ARE MADE.

BRICKS are made of clay. While the clay is wet and soft, it is shaped by hand or by a machine, and then it is laid aside to dry. As it dries, it becomes hard, and in some countries where there is little or no rain, as Egypt or Syria, when the clay is thoroughly dry, the brick is finished. But in countries like England, where it very often rains, such sun-dried bricks, as they are called, would be of little use. After heavy rain they would become soft again, and the walls of the houses which were built of them would bend or tumble down, especially if they had heavy roofs, fire-places and windows to bear. In order to avoid such accidents as these, it is necessary to alter the clay in such a way that the bricks will not be made soft again by being wetted. This is done by baking the bricks with fire. This also makes them much harder and less liable to break, and they are much better for use in almost every way than sun-dried bricks are.

Many bricks are now made by machinery; but I do not wish to tell you anything about this now, as I am afraid you might not be able to understand an account of the machines, and so you would not be interested. But many millions of bricks are still made by hand, even in England; and I think you will have no difficulty in understanding how this is done.

It is not every kind of clay which will serve for brick-making. If there are any stones in it, for instance, it will not do; and there are many other ways in which it might be spoiled for brick-making. A certain amount of sand in the clay is found to be very useful, because it prevents the bricks from shrinking or cracking when baked, and very often brickmakers mix sand with their clay for this purpose. But in some places clay of just the right sort is found, and no mixing of any other material is necessary. To the place where this clay, or brick-earth as it is called, is found, the brickmaker brings his tools, and opens out a brickfield.

The sods and the upper soil are first removed from a portion of the field, so as to lay bare the clay in a hollow. Before any bricks are made, the clay is dug over and beaten about a good deal with shovels and rakes. It is left exposed to the rain and

frost during the winter, and may perhaps even be dug over once or twice during this time. All this helps to mix the clay, and makes it soft and fine for working; and it is ready for making into bricks when spring-time comes.

The brick-makers work in gangs or groups of four or five. One of the men makes the bricks, another brings him the clay, and a third takes away the bricks as they are made. Besides these, there may be another man digging the clay in the pit, and perhaps another who acts as a foreman, and sees that everything is properly done.

The man who shapes or moulds the bricks works at a table, often in the open air. In one part of the table there is a small trough containing water, and by the side of it there is a little pile of sand on the table-top. The man who brings the clay from the pit, heaps it up in a small lump on one end of the table, within easy reach of the brick-moulder.

It is possible to make rough, clumsy bricks by pressing the clay with our hands, and beating it upon a flat board in order to get the sides straight. This method will not do, however, for the man who has to earn his living by making bricks. For one reason, it is not quick enough. Then, again, the shape of the bricks would not be sufficiently neat.

Such bricks would not make a straight wall. But there is a still more important reason why this simple way of making bricks would not do. All bricks have to be made exactly of the same size, and it would be far too troublesome to do this by hand alone, and to be continually measuring. So the brick-maker has one or two simple tools. The most important one is a brick-mould. This is a frame of wood, the inside of which is exactly the size which the clay brick is to be. The frame is just the depth of the brick, and as it lies flat on the table, it forms a sort of trough, of which the table-top is the bottom. When the brick-moulder is going to make a brick, he sands the inside of the frame, and taking a piece of clay from the lump on the table, he fills the trough of the frame with it, pushing it tightly into every corner. Then he takes up another tool, shaped like a ruler, and, resting it on the upper edges of the frame, he scrapes off all the clay which stands up above the frame or trough. The boy who is carrying the bricks away takes up the frame from the table with the clay brick in it. The brick-moulder takes another frame, and begins to make another brick, while the boy shakes the first frame gently, and the clay brick falls out of it on to his barrow.

When his barrow is loaded, the boy wheels his bricks away to another part of the field, and lays them out in rows upon the ground, so that they may dry in the sun. When the first row of bricks has dried hard, another row is laid upon the top of it, and by and by another row upon that, and so on until there is a low but thick wall of sun-dried bricks. All the time that these bricks are drying, they must be covered up when it rains, lest they should be wetted, and become soft, and lose their shape.

In the course of a few weeks many thousands of these sun-dried bricks are made ready for burning. They are all burned together in another part of the brickfield. A layer of broken bricks is spread upon the ground, and sprinkled with small coal, and upon this the sun-dried bricks are built or stacked in a great open pile; that is to say, the bricks are not set close together as in a wall, but spaces are left, ruuning through the pile in all directions. Between the bricks, as they are laid, small coal is scattered. Last of all, the pile is surrounded by rows of old burnt bricks. When all is ready, a small fire is lighted, close to the pile, and the flames from it set fire to the coal sprinkled in the pile. In a little while the whole heap is on fire. It is like a huge

bonfire burning in and out of a pile of thousands of bricks, which speedily become red-hot. The fire burns for days before it goes out. When the bricks are cool again, they are no longer clay, but true bricks, such as are used for building houses. Many are cracked or burnt by the fire, or spoiled in other ways, and these have to be laid aside as waste. But by far the most of them are sound and ready for use by the builder.

HOW IRON RODS ARE MADE.

WHOEVER has lived in any large town for some time will often have seen in the streets waggons loaded with sheets of iron, or long iron rods tied up in bundles. If you look at one of these bundles you will find that it is not tied up with cord, but bound round with short pieces of iron rod, which have their ends twisted round each other into a kind of knot. As I have already said that the pig-iron which is obtained from the blast-furnace cannot be hammered or bent without breaking, it is quite plain that these pieces of iron rod are very different from pig-iron. The iron of which they are made is commonly called *wrought-iron*, which means simply *worked-iron*. When I have told you how wrought-iron is made, you will see that the name is a very suitable one.

Wrought-iron is made from pig-iron. The impurities which remain in the iron when it comes out of the blast-furnace makes it brittle like glass. When glass is made hot,

however, it becomes first of all soft and pliant, and then melts. But when pig-iron is heated, it never becomes pliant, but melts at once from a solid to a liquid, as ice melts to water. For this reason it cannot be bent, either when it is cold or when it is hot. As it is the impurities of the pig-iron which make it act in this way, the iron-maker who wishes to make a better kind of iron tries to to get rid of these impurities. He does this step by step.

The first step is to pass some of the bars of pig-iron through a furnace, which is very much like a small blast-furnace. This furnace is called a *refinery*, because it refines the metal, or makes its purer.

Into the hollow of the furnace coke and pig-iron are placed, and blown by the blasts from several pipes. The iron melts, and is partly purified by the heat and the hot air, as in the true blast-furnace. It gradually falls to the bottom of the furnace, and at the end of two hours it is allowed to run out into a narrow, flat mould, where it quickly cools. It is still brittle, but it is much brighter and finer. It is broken up into pieces, and is ready for the next operation, which is called by the strange name of *puddling*, because the workman stirs the melted metal about as if he were trying to make a puddle of it.

Puddling is one of the most important operations in making iron, and I wish to make it quite plain to you how it is done. If you have ever seen any large ironworks, or forges, you will have noticed fiery flames rushing out of some very tall and narrow iron chimneys, which have a sort of lid at the top, which may be opened and closed by means of a rod and a cord. These are the chimneys of the puddling-furnaces. The furnaces themselves are long and narrow, and a little taller, perhaps, than a man. Each of them has a chimney at one end and a fire-place at the other. Between these there is a sort of large oven, which is open to the fire-place on one side, and to the chimney on the other, so that the flames from the fire have to pass through this oven in order to escape up the chimney. There is a little dam or low wall between the oven and the fire-place, over which the flames must pass on their way to the chimney. This low wall throws the flames towards the top of the oven, which is made low and arched so as to lead the flames just over the bottom of the oven without touching it. In front of the oven, or furnace, there is an iron door which slides up and down, and is moved by a long iron rod and chains. In this door there is a small hole, like the entrance to a

dove-cot which is always open, and through this hole the puddler can see what is going on inside the furnace, although it is almost too dazzling to watch.

Closing the chimney, so as to stop the draught, the puddler loads the bottom of the furnace with pieces of iron from the refinery. He then closes the iron door and lifts the cover from the tall chimney, by pulling a cord. Immediately the fierce flames rush from the fire-place, through the furnace over the top of the iron, into the chimney. The iron grows hot, and in a little more than a quarter of an hour melts. The puddler, taking a long, heavy iron bar, pokes it through the hole in the furnace-door, and begins to stir up the melted iron, to *puddle* it, as he says. After a while the iron bubbles, and blue flames rise from it. As the workman continues to stir the iron, he finds his work grows harder and harder, because the iron becomes less fluid. Although it is as hot as ever, it becomes more and more pasty, and begins to stick like dough to the end of his rod, making it heavy and hard to move. Still he must keep stirring, because this is the only way of gathering up the iron from the other impurities which have melted with it. Little by little the puddler, gathering his iron as a rolling snowball

gathers snow, rolls it into four or five balls, which he places one by one upon the wall between the furnace and the fire-place, to wait until he has got all the iron that he can out of his fiery bath.

When he has made all the balls he can, he opens the door of the furnace, takes one of them out, and places it on a little iron cart. A boy wheels it away to a great hammer, which is moved by steam. While one man works the hammer, another one takes the red-hot ball and holds it under the hammer-head. At every thump sparks and splashes of impure slag are beaten and squeezed out of it.

Near to the steam-hammer there are several huge iron rollers, arranged in pairs, like the rollers of a wringing-machine. Some of those rollers are smooth, while others are notched in rings like the grooves of a number of pulleys placed side by side. When they are notched or grooved, the largest groove is at one end, the next groove is a little smaller, the next smaller still, and so on to the end of the rollers. All these rollers are made to go round by a powerful steam-engine. When the ball, or *bloom*, as the workmen call it, has been sufficiently hammered by the steam-hammer, it is taken, while still hot, and made to go through the

largest groove of the rollers. This makes it a little longer, and at the same time a little narrower. It becomes, in fact, a bar of iron. It is passed through the other grooves of the rollers, one by one, becoming a little narrower, until at last it is a rod of iron.

The iron is not yet, however, ready for the market. It is not quite good enough, although it is now very different from pig-iron. To make it ready for the market the rod of iron is cut up into short lengths, which are made into little bundles, and fastened with iron wire. A number of these bundles are placed in another furnace similar to the puddling furnace, and are heated once more. When white-hot they are taken out, hammered into one lump under the steam-hammer, and rolled into rods as before. These rods are straightened with a small hammer, and are then ready for the market, or for the use of the blacksmith. Some of the balls from the furnace are passed between a number of plain rollers, which flatten them into sheets. The edges of the sheets are cut straight with a pair of huge shears or scissors, moved by steam, and the sheets themselves are straightened with hammers, after which they are ready for use.

These rods and sheets can be hammered and bent to almost any shape without break-

ing, especially when they are heated, for heat makes them soft and pliant. It is almost impossible to melt them. If two pieces of the rods or sheets be made hot, they can be hammered together in one piece, and they will join together so closely that they cannot afterwards be separated at the joint. All wrought iron is like this, and, as you see, it is greatly changed by the refining and puddling which it has undergone.

HOW PAPER IS MADE.

WHEN you have seen a ragman gathering rags from door to door, or seen his barrow loaded with its pile of dirty remnants, have you ever asked yourself what he is going to do with them? We may be sure that they are useful, otherwise the ragman would not take the trouble to collect them. He sells them to rag-merchants, who sort them into different lots, and then sell them again to certain manufacturers, who make use of them in various ways. Some of the rags are torn to shreds, mixed with wool, and used for making an inferior kind of cloth. Large quantities of them, especially linen rags, are used for making paper.

When the rags are to be made into paper, they are first carefully sorted, and cut into small pieces by women. The finest linen rags are put by themselves, for these only are used in the manufacture of the best writing paper, while inferior linen rags and cotton rags are placed in other piles, according to

the quality and kind of paper which they will make. The rags are next washed with hot water or steam, and afterwards bleached by means of chemicals. They are then placed in a machine, which tears them up so small that they are turned into soft pulp, in which there is not a particle of the woven cloth left. This machine is a kind of trough or vat full of water, in which there is a drum covered with sharp spikes, which is kept turning round and round. At the bottom of the trough other spikes, or cutters, are fixed, between which those upon the drum pass, as the drum turns round, and the two sets of spikes tear the rags to pieces. The rags are kept in this machine for several hours, at the end of which time they are like so much white mud mixed with the water. This mixture, or pulp, is conveyed away to a large vat, which is kept warm, usually by means of steam.

At the present time most paper is made by machinery, but the best is still made by hand. As the making of paper by hand is easier to understand, I will describe that first, and then tell you something about the machinery which is now used in place of hand labour. The paper-maker, or dipper, as he is sometimes called, stands by the side of the vat which is filled with the paper-pulp,

or paper-mud, as we might call it. He has in his hand a *mould*, which is nothing but a square frame of wood filled in with fine wires woven in and out very like the threads of a piece of cloth. He has also another very thin wooden frame, called a *deckle*, which he can fit upon the top of the mould so as to make a little raised edge, very much as a flat picture-frame makes a raised edge to the picture which is placed in it. Fitting the deckle and the mould together, he dips them like a dish into the paper-pulp, and draws a dishful of pulp out of the vat. He shakes his mould from side to side in order to spread the pulp into every corner, while the water runs out through the wire-cloth at the bottom of the mould, and leaves a thin sheet of pulp, like a little layer of white mud, upon it. The paper-maker puts the mould aside, and takes up another to dip it in the same way, using the same deckle as before.

When the mould has rested a few seconds to allow all the water to drain away, it is taken up by another workman, called a coucher, who turns the mould over, shakes off the sheet of stiff pulp upon a sheet of woollen cloth, and places another cloth upon the top of it. He returns the empty mould to the dipper, takes up another which has

been dipped, and shakes off the sheet of pulp in the same way. One by one these sheets are laid upon the top of each other, with cloths between every pair of them, until a pile of several sheets has been made. This pile is then placed in a strong press, and powerfully squeezed in order to force out all the remaining moisture, and, at the same time, compress the sheets of paper. They are next pressed several times without the cloths, after which they are hung over cords to dry.

When the sheets of paper are dry they are quite firm and strong, but they are not glossy like writing paper. They are dull and porous, rather like blotting paper, and if we attempted to write on such sheets the ink would run, and become blurred, until it would be impossible to read the writing. To remedy this defect the sheets are sized; that is to say, they are dipped, a few at a time, into size, which is a sort of thin, weak glue, prepared from scraps of leather, hoofs, and skins, and mixed with a certain quantity of alum. The size fills up the small holes in the paper, and sets upon the surface, making it smooth to write upon. The sheets are again dried, pressed several times, and then folded or cut as may be required.

When paper is made by machinery the

pulp is allowed to run out of the vat upon a broad web, made of woven wire, like that which forms the mould of the hand-dipper. This web is several feet long, and it is what machine-makers call *endless*, by which they mean that its ends are joined together, as is the case with those leather belts which drive sewing-machines, threshing-machines, motor-bicycles, and many other kinds of machines. The endless web of the paper machine is kept tight and flat by two rollers, one of which is near the vat, and the other several feet away. The web passes round these rollers, and when they are turned the web is made to go round and round, from the roller near the vat to the other one, and back again underneath to the first one, and so round again. At the same time, by another kind of mechanism, the web is made to sway from side to side a little. When the watery pulp flows from the vat upon this web of wire-cloth, this swaying motion spreads it evenly over the web, while two raised leather straps placed at each side prevent the pulp running off the sides. The water runs through the web, just as it runs through the bottom of the dipper's mould, and leaves a thin sheet of stiff pulp spread evenly upon the web. As the web moves on from the vat to the other roller, it bears this sheet of pulp along

with it, and when it has gone a certain distance it passes under a roller covered with cloth, which presses the pulp and sucks up some of its moisture. When the web reaches the second roller, and begins to turn back, the paper itself is seized by certain rollers, which carry it on to another endless web, which is made of cloth. This web passes the paper between other rollers, which dry it and press it still more. In this way it is carried to and fro, and passed between a number of rollers, some of which are made hot with steam, and dry the paper very quickly, while others are very smooth, and give the surface of the paper a beautiful polish. The pulp which falls upon the first endless web is made into paper before it leaves the machine, and the work which would take the hand paper-maker many days is performed by the machine in a few minutes. As the pulp is always flowing into the machine there is no break in the paper, and it is rolled up in one long roll, which may contain a mile or two of paper. Some printing machines use these rolls just as they are; but for most purposes the paper has to be cut up in various sizes.

HOW LOOKING-GLASSES ARE MADE.

IF you have ever seen a piece of broken looking-glass, or if you have seen a looking-glass taken out of its frame, you will know that it is simply a rather thick sheet of glass with a thin coating of something on the back of it. The outer side of this thin coating often shines like dull silver, and it is usually called the silver or silvering of the looking-glass, though there is really no silver in it. Sometimes, however, the back of the glass is red or brown, and does not glitter at all. When this is the case, the back of the silvering has been covered with a red or brown varnish as a protection from damp or scratches.

If we wish to understand how looking-glasses are made, we must learn what the silvering really is, and how it is placed upon the back of the looking-glasses. But before we try to do this, it will be interesting and

instructive to see how the glass itself is prepared for the silvering. We have already learned how glass is made by melting together sand, lime, and potash or soda; and we have seen how the glass-blower blows the glass into the shape of bottles. The glass which is intended for mirrors is melted in the same way, but a little more care is taken in selecting the sand and other materials, so as to get very good and clear glass. But when the glass is taken from the furnace, it is not blown by a glass-blower, but used in a very different way. Near the furnace there is a large iron table, with a very smooth, flat top. Along the edges of this table there are moveable strips of iron, which can be raised or lowered so as to make a higher or lower rim along each side of the table. Upon the top of the table there is a large roller, which is long enough to reach across the table and rest upon the raised edges on each side of it. The table is placed upon wheels, so that it can be easily moved from place to place.

The glass is melted in large pots. When it is ready for use, a pot is lifted out of the furnace by means of a crane, and carried over the top of the table. The pot is then overturned, and the glass flows out, like a lump of dough, upon the middle of the table.

The workmen push the roller along the table, and roll the glass out like a cake until it covers the whole of the table-top to the level of the iron rims, which stand up along the sides. The moment this is done, the table is wheeled to the door of a kind of large oven, and the sheet of hot glass, as soon as it is stiff enough to be moved, is taken from the table, and placed flat upon the bottom of the oven. It is sprinkled with sand, and other sheets, as they are made, are placed upon the top of it. When the oven is sufficiently full, it is closed for two or three days, and the glass plates are allowed to cool very slowly. This is necessary to prevent their cracking. When cool, they are taken out, and the edges are cut square with a diamond. Sheets made in this way are known as *plate-glass*, to distinguish them from sheets and other objects of glass made by blowing; for, I may tell you, sheets of glass can be made by the glass-blower.

When the sheets of plate-glass come from the oven, they are rough and dull, and quite unfit for using at once for windows or looking-glasses. They must first be polished smooth and clean. This used to be done by rubbing them by hand with emery and other powders, but it is now done by machinery.

In some of the machines two plates are rubbed against each other, with sand and powder between them, and in this way two plates are smoothed at once. As the work goes on, finer and finer powder is used, until at last, after a quarter or more of the sheet has been rubbed away, the surface is as smooth and clear as it can be made. It is then ready for placing in shop windows, or for being made into a looking-glass.

The silvering of looking-glasses is partly tin, and partly quicksilver or mercury. The tin is smelted from an ore, in very much the same way that iron is smelted, and it is then beaten with hammers into a large, thin sheet, like silvery paper. Tin in sheets of this kind is usually called tin-foil, and much of it is used for wrapping up chocolate and other sweets. The tin which is used by tinners for making pans is really iron coated with tin on both sides. Quicksilver is the bright, silvery liquid which we see in thermometers and weather-glasses.

When a looking-glass is to be made, a sheet of stout tin-foil, a little larger than the glass, is laid on a very smooth, flat table, and the creases are taken out with a brush. A little quicksilver is spread over it with a hare's foot, and quickly soaks into it. More quicksilver is poured on the tin, until

it runs all over it, and covers it like so much water. Then the sheet of glass, which has been carefully cleaned, is brought to the table, and gradually slid over the quicksilver and the tin, in such a way as to drive before it any bubbles of air which may be between the quicksilver and the tin.

Quicksilver is very heavy, so heavy, in fact, that glass will float upon it as a cork floats upon water. When the sheet of glass has been pushed over the tin-foil and the quicksilver, it is actually floating upon the quicksilver. It is loaded with heavy weights to press it down upon the tin, and to squeeze out all the quicksilver which has not soaked into the tin. In about twenty-four hours the tin-foils sticks to the glass, which may be then tilted up a little to allow any quicksilver which remains to run off. The looking-glass is allowed to dry for some days, or even for a week or two, by which time the quicksilver and tin-foil are firmly fixed to the glass like a coat of paint or varnish. The back of the silvering is dulled by the air, but the side next the glass is bright and smooth as polished silver. It is this bright surface which reflects the appearance of things which are placed before the mirror while the glass itself is only a protection for the silvering, keeping it from

breaking, or becoming scratched, or losing its brightness. Sometimes, as I have said, the back of the silver is varnished, and then the glass is ready for its frame.

HOW THREAD IS MADE.

WHEN we speak of thread we usually mean the black or white sewing-thread, which is sold to us wound upon wooden bobbins, and is used for stitching and mending clothes. This thread is made from cotton wool, which is obtained from the cotton-plant. But there are several other kinds of thread, some of which are made from materials obtained from plants, while others are made from the hair or wool of animals. The woollen or worsted threads of which stockings are knitted are made from the wool of sheep, and it is the making of these kinds of thread which I wish to describe, because you know what the wool is like to begin with, and because these threads are also used in the making of cloth.

We have seen how the fibres of the hemp are twisted or spun into twine and ropes.

Threads of wool, and, indeed, all kinds of thread, are spun in a very similar way. But before the wool is ready for spinning it has to be carefully prepared. It is shorn from the backs of the sheep by the farmers, and sold to the wool-merchant, or manufacturer. It is carefully sorted, then washed and dried, after which it is roughly shaken and combed to take out the dust, thorns and seeds which have found their way into it. It is combed again, and it is then ready for spinning.

If we take a few hairs of wool, and roll them together between our fingers and thumb, we can easily make them into a coarse thread. Some savages make all their thread in this slow way. Perhaps you will wonder, though, how it is that short hairs can be made into a long thread. The truth is that the ends of some of the hairs come against the middle of others. The bundles of hair, as it were, overlap, one after the other, some a little, some a great deal, and so they stretch on in a long line or thread. The surface of each hair is covered with tiny scales, which can only be seen with the help of a microscope. These scales act like hooks, and one hair hooks tightly into another when they are twisted together.

In many countries, such as Italy and Switzerland, we may see women making

thread with the distaff and spindle. The distaff is a long stick, or staff, and the spindle is a short, thin one with a metal ring round the middle of it. The spinner wraps the combed wool round one end of her distaff, and sticks the other end in her belt. Drawing a few hairs out of the bundle on the distaff, she twists them into a thread, and fastens it to the end of the spindle. Then, as the spindle hangs in the air, she gives it a sharp twirl. As it spins it twists the thread by which it is suspended from the distaff, and its own weight tends to drag out more hairs from the bundle. The spinner helps the spindle by drawing out the wool, and pressing it into a neat and even thread. As the thread lengthens, the spindle falls lower and lower, but before it reaches the ground, the spinner seizes it, winds the thread which is already made round the middle of it, and fastens it in a notch, in much the same way that sewing-thread is wrapped and fastened on a bobbin. Then she gives the spindle another twirl, and spins out another length of thread. This is repeated again and again, until all the wool upon the distaff is spun into thread.

By means of the distaff and spindle, thread is made much more quickly and much better than it can be twisted between the fingers

and thumb. If we could place the spindle in a kind of frame, and make it go round by means of a wheel and handle, we should have a spinning-wheel rather like that which is used by the rope-maker. Our great-grandparents used such spinning-wheels for making thread. The wheels were smaller and lighter than the rope-maker's wheel, however, and one person could do the spinning alone; and the spinner not only spun the thread, but wound it upon the spindle or bobbin, too, first spinning a short length of thread, and then winding it, as the woman does who works with distaff and spindle. These hand spinning-wheels were a great improvement upon the distaff and spindle, and enabled the spinner to make a great deal more thread than she could before.

And now I wish to take you into a great mill, and describe to you how thread is made to-day. It is spun upon a large machine, which is called the spinning-mule. One part of the mule is fixed, like a long frame, near the wall, while another is a kind of carriage running upon rails, stretching out from the frame towards the middle of the room. On the top of the carriage there are a great many long, narrow bobbins, or spindles, arranged in a row, all pointing at

the frame, like a row of toy cannon ready to bombard it.

The wool has already been partly twisted before it is brought to the spinning-mule. This is done by the machine which combs it, the *carding-machine*, as it is called. As the wool comes out of this machine, it is divided into narrow strips, each of which is rubbed by means of leather bands into a roll, which looks very much like the roll of tobacco in a cigarette, with this difference, however, that the tobacco-roll is short, while the roll of wool is long, and is wound like a soft cord upon a large reel.

A number of these reels of loosely-twisted wool are brought to the spinning-mule, and placed in the frame. There are as many reels as there are spindles upon the carriage of the mule. The cord from each reel is passed through two or three pairs of tiny rollers in the frame of the mule, and then fastened to the spindle on the carriage which is opposite to it, the carriage being drawn up to the frame as near as possible.

When all is ready, the spinning-mule is started. The little rollers go round, and draw the cord off the reels. The carriage begins to move away from the frame, drawing out the thread from the rollers, just as the rope-maker walks backwards along the

rope-walk while he is making the rope. At the same time all the spindles on the carriage are made to whirl round very quickly. As they point towards the frame, they do not wind up the threads coming from the rollers, but simply spin them round and round, and so twist them as the rope-maker's whirls twist his twine. When the carriage has run back a few feet, it reaches the end of the rails upon which it runs, and stops. At the same instant the little rollers stop, so that no more cord is drawn off the reels, and the spindles on the carriage cease to spin. Then a strange movement takes place. For a second or two the spindles go slowly round in the opposite direction. This uncoils a little of the thread which has been previously wound round each spindle, and leaves it rather slack.

A number of bent arms, like sickles, move up and down on the carriage, catch hold of all the threads, and bend them round in such a way that the threads come on to the spindles at the side, instead of at the end, as before. As soon as the bent arms have done this, the carriage begins to move towards the frame, the spindles begin to turn again slowly in the proper direction, and the thread which was spun before is now wound upon the bobbins of the spindles. When the

carriage reaches the frame again, a length of thread has been made, and the mule is ready to repeat the work.

Thus, as you see, the spindles of the spinning-mule are like so many tiny rope-makers moving to and fro along their little rope-walk, twisting the thread as they go backwards, and winding it as they go forwards. Hundreds of them are at work at once, and, so long as any one will tend them, they never weary, and they never stop.

HOW STEEL IS MADE.

IF you have ever broken up a mechanical toy, such a one, for instance, as the little locomotives which are wound up with a key, you will perhaps have noticed a small round box, about the size of a pill-box, in which there is coiled a long piece of iron like a rolled-up tape. This coil of iron is the spring of the toy, and the part which receives the movement of your hand when you turn the key, and by and by lets it go again into the wheels of the engine. If the spring should by any means get out of its box it will spread out to a much larger size, and though you will find that you can roll it tighter with your fingers, you will not be able to coil it sufficiently tight to get it back into the box again.

I have said that the spring is made of iron, but it is really very different from either cast iron or wrought iron. It can easily be bent, but the moment it is let go, it springs back to its first shape. This is the reason that it is called a spring, and it is this jumping back to its old position, as it were, which drives round the wheels of the toy and makes it go. Now, cast iron cannot be bent at all, and wrought iron, when it is bent, never springs back to its old shape. The spring is a special kind of iron, known by the name of steel. All springs are made of steel, from the heavy springs under railway carriages, to the tiny spring of a watch, which is scarcely thicker than a hair. But springs are not the only things which are made of steel. It is also used for knives, razors, and scissors, for chisels, planes, and saws, for the rails of railways, and for the great plates which are put upon warships to protect them from cannon shots. In fact, the striking thing about steel is that it can be put to so many uses, and its qualities changed in so many ways, by the skilful men who know what to do with it in order to give it those qualities which they require.

Before I can tell you how steel is made, I must try to make you understand why it is different from cast iron or wrought iron.

Wrought iron, as I have already told you, is pure iron; while cast iron is iron which has received some impurities from the coke and other substances which are heated with the ore in the blast furnace. If we char a piece of wood until it is black we change it into charcoal. Coke, which is made from coal, is practically charcoal, too. Nearly the whole of the impurity in cast iron is simply charcoal, and it is this which makes it so different from wrought iron. In the puddling furnace the charcoal is burned out of the cast iron, and this, more than anything else, turns it from cast iron to wrought iron.

I have told you how some savages make very good iron by digging a hole in the ground, lighting a fire in it, placing ore and charcoal upon it, and blowing the fire with their bellows. The iron which they make in this way is really wrought iron, though it has never been puddled. It has passed through the fire without receiving any of the red-hot charcoal of which the fire is made, and so it comes out as wrought iron instead of cast iron. But sometimes things go wrong, and, when the savage takes out his lump of iron from the bottom of the hole, he finds that it is harder than usual. He does not know what has really happened, but Englishmen who have examined these lumps of iron

find that they are really steel. The savage has, in fact, made steel by accident. A very little of the charcoal in his fire has got into his iron and turned it into steel. If a great deal of the charcoal had got into the iron, as happens in the English blast furnaces, the iron would have been turned into cast iron. Try to remember this, because it is very important. A little charcoal in the iron makes steel; a good deal of it makes cast iron.

Now, there are perhaps nearly a dozen ways of making steel used in various places. I can only tell you of two, however. In one process the steel is made from wrought iron, in the other it is made from cast iron. We will take the wrought iron first. In order to make it into steel, a very little charcoal has to be added to it. The steel-makers take some boxes or cases, made of baked clay, which, like the glass pots of the glass-maker, will bear a great heat without cracking. These cases are loaded with charcoal, in the midst of which a number of bars of very good wrought iron are buried. The cases, when filled, are carefully closed, and placed in a furnace somewhat like a glass furnace, where hot flames can surround them on every side. The cases remain in the furnace from eight to fifteen days, and the

iron and the charcoal within them become red-hot, and little by little some of the charcoal passes into the iron. When the bars are taken out they are rough and blistered, but they are turned into steel. The process is called *cementation*.

The other process which I am going to describe is called the *Bessemer* process, after Sir Henry Bessemer, the man who invented it. In this process cast iron is turned into steel by burning out of it some of its charcoal. This is done in a *converter*, a large egg-shaped vessel which swings on trunnions like a short, thick cannon. It acts like a small blast furnace hung in the air. A blast pipe passes through one of the trunnions, and down the outside of the converter to a box at the bottom. There are a number of holes leading through the top of this box to the inside of the converter, and when the blast is blowing it passes through these holes. The inside of the converter is lined with clay, cement, or lime, to resist the heat, and by means of suitable machinery it may be easily turned over, or turned about in any direction.

The converter is first turned upon its side, and several tons of cast iron are allowed to run into it from a furnace. The blast is then started, and blows through the holes in the

bottom of the converter with a great rush. The huge vessel is turned straight up, and the melted iron covers the bottom. The blast through the holes is so strong, however, that the iron cannot run through them into the box below, but the air rushes through the iron in the converter, and blows out a grand shower of sparks. While the blast is passing through the iron it is burning out the charcoal, and at the same time it is making the iron hotter, just as the wind of a pair of bellows make a fire hotter. If the workman could stop the blast when sufficient charcoal had been burned out of the iron, he would have changed it into steel. But, unfortunately, it is very difficult to do this. If he stops the blast a minute too soon, or a minute too late, all his iron is spoiled. So he finds it better to make his steel in a roundabout way. He lets his blast go on until *all* the charcoal is burned out of the iron, then he turns the converter on its side again, and stops the blast. Once more he runs a little cast iron into the converter from another furnace, turns the converter up again, lets the blast blow for a few seconds, and his steel is made. The charcoal of this new supply of cast iron spreads through the whole of the iron in the converter, and, of course, it is a very little quantity for so large

a mass; just enough, in fact, to make it steel. The workman turns over the converter—empties the steal into a huge ladle, and commences again with a new supply of cast iron.

HOW BUILDING-STONES ARE MADE.

YOU will perhaps think it rather strange that I should talk of building-stones being made, for everyone knows that stone is found in the ground, ready-made, and only needs to be broken up and chipped into the proper shapes for use. I often pass a number of quarries from which stone is taken for building purposes, and when I see the various labours which are going on in those quarries, I cannot help thinking that, though the stone itself does not need making, it requires as much labour to be spent upon it before it is ready for use as limestone does before it is converted into lime. It is the labour of these quarrymen and stone-cutters which I wish to describe.

The qualities of stones vary very much. Some are very hard and difficult to cut, and cost a great deal more in the labour of

shaping them than others do. Some are soft and easily broken up by frost and rain, and the house which is built of them soon loses its neat appearance. Some have a good colour, while others are spoiled by streaks and knots of a different colour from the rest of the stone. Very often, too, these streaks and knots are softer or harder than the rest of the stone, and are affected by the weather more or less than the other parts. In opening a quarry a good deal of practical knowledge and judgment are necessary to select a proper stone, and though there is stone of some kind in every part of the country, builders will often send many miles to get the exact kind of stone which they require.

Quarries are generally opened at the foot of a slope, so that the quarrymen dig into the side of a hill rather than down into a pit. When this can be done the stone is drawn and carted away on level ground, instead of having to be lifted up from a deep hole; but the quarrymen must excavate where the stone is, and, as the work goes on, the quarry often becomes deeper as well as larger. As a rule, the rock is near the surface, and only a little grass and soil have to be removed before it is laid bare. When the rock is laid bare, the workmen

begin to break it up with their sharp-pointed hammers, picks, and iron wedges, into pieces as large as possible.

If we look at any quarry which has been worked for some time, we shall find a large hole, with high, bare rocks on perhaps every side but one, where there is an entrance, with a cart-road leading from the bottom of the quarry to the level of the ground around it. The bare walls are cut into ledges or steps wide enough for the workmen to stand on and break away the rock in front of them. When a workman wishes to bring down a new block, he takes a sharp-pointed hammer and begins to make a small hole on the top of one of the ledges. By repeated and steady tapping with the point of his hammer, he makes a small hole a few inches deep, and in the same way he makes several other holes, a foot or two feet apart, in a line along the ledge. When the holes are finished he places in each a sharp-pointed steel wedge, and, hammering first one and then another, he drives them deeper and deeper into the rock. Presently the rock cracks or splits in a line from wedge to wedge, and a huge block is broken from that ledge, and falls upon the ledge below, or is lifted away by means of a crane, and lowered to the bottom of the quarry.

The size and shape of the blocks which are broken off depend almost entirely upon where the quarrymen chip the holes into the rock, for the rock splits in nearly straight lines from one hole or wedge to another. When a very large block is to be removed, the quarrymen make use of the crane for splitting the block, as well as for lifting it away. The holes are made as before, but long crow-bars are placed in them in place of the short steel wedges. When the crow-bars have been driven well into the rock, and are firmly embedded in it, the chain of the crane is fastened to one of them, and two men, turning the windlass, wind up the chain, and pull the block away from the rock. Though the rock looks so solid, there are always slight flaws in it, and little by little it splits along those nearest the crow-bars, as the quarrymen pull with the chain of the crane, first at one crow-bar and then at another.

When the blocks are lowered to the bottom of the quarry, they are split into their proper sizes by other workmen, who make holes in them and drive wedges into them in exactly the same way. But as the stones become smaller, smaller wedges are used, and the blocks split more quickly. Many are cut square, like large bricks, and

of a convenient size for building, and these are chipped smooth on their sides by masons using hammers and chisels. The fronts of these stones, which are turned outwards when the house is built, are often chipped over with pointed hammers, which leaves them rough, but not very irregular. All this work is done before the stones leave the quarry.

The large flagstones which are used for paving causeways are sawn from a huge block of stone with the aid of machinery. The saw is a large, square frame of wood, with thin but broad blades of steel set in it. The frame is suspended horizontally from a strong and lofty structure of wood, in such a way that it may swing to and fro a little, and the blades are set in the frame like bars with their edges downwards. These blades are four or five inches deep, from the lower edge to the upper one. They are very thin, but not toothed, as carpenter's saws are. A long arm is joined to one end of the frame of the saw, and connected at the other to a wheel, which is turned round by means of a steam engine. As the wheel is driven round, the arm is moved to and fro, and sways the saw-frame backwards and forwards. The large block of stone which is to be sawn up is placed on a low car, and

pushed under the saw. The saw is set in motion, and as it swings to and fro, the blades saw along the top of the stone. As the saw works on, suitable wheels and rods are made to move, by means of which the chains which hold up the frame of the saw are allowed to unwind from a roller, and the frame with its saw falls lower and lower, until the saws pass quite through the stone. Water is allowed to drip continually upon the stone and the saws from a trough above. The saws are set a few inches apart, and the stones which are left standing between the blades, like so many slices of toast in a toast-rack, are the flagstones. If the saws are placed nearer to each other, the flag-stones are cut thinner, and if the saws are set further apart the stones are thicker.

Very often, when the quarry is excavated to a great depth in the ground, water flows into it from the surrounding ground, and fills the bottom of the quarry so that the men can only work at the sides. But if the stone is good, and the water is not very abundant, the owners lay down pumps and set up an engine to work them, and by continual pumping they succeed in keeping all but a very small portion of the quarry sufficiently dry for the men to work. When this is the case, one part of the quarry is dug

out deeper than the rest, so that all the water may flow into it as into a well, and the pipes of the pumps are carried down into this well.

HOW SALT IS MADE.

THE sea contains an inexhaustible store of salt, from which men have drawn great supplies for many centuries. This salt is dissolved in the water, just as the sugar which sweetens our tea is dissolved in the tea itself. We cannot detect, either by sight or touch, whether there is salt or sugar in the water or the tea, but we know in a moment if we taste the one or the other.

If we put a little too much sugar in a cup of tea, some of it remains undissolved. If we poured off the hot, sweetened tea into a clean cup and allowed it to cool, we should probably find a few grains of sugar, or at least a little sugary syrup, at the bottom of the second cup. If we put out tea in a pan over the fire and boiled it away, we should find all the sugar which we had put into it left behind in the pan. It is clear, from

these observations and experiments, that tea, or water, will only dissolve a certain amount of sugar, more when it is hot than when it is cold, and that when the water evaporates it leaves the sugar behind.

If we made similar experiments with salt and water, we should find that they act in the same way as the sugar and the tea. Water will not dissolve more than a small amount of salt, and when the water evaporates it leaves the salt behind. In hot dry countries it sometimes happens that shallow bays and lagoons, which have been flooded with sea-water at very high tides, are afterwards dried up entirely, and the salt which was dissolved in the sea-water is left behind, covering the ground like a sheet of dazzling snow. In Syria and Cyprus, salt formed in this way—natural salt, we might call it—is gathered together into heaps, and carried away for domestic use.

The simplest and cheapest way of making salt from sea-water is to copy this natural process. Such is the process at the Government salt-works in Sardinia. The water of the sea is pumped into a number of large, shallow reservoirs and allowed to evaporate by the heat of the sun. The work goes on quickly during the hot summer months, from June to October, but slower in the colder

months, and in the course of the year many thousands of tons of salt are obtained in this way.

Most hot countries still adopt this method of making salt, and even in England it used to be followed, to some extent, when our grandfathers were young. It is a very cheap method, because the sea-water and the sun's heat cost nothing, the labour is not great, and very little machinery of any kind is necessary. But the process has also great disadvantages. The salt is not very pure. Not only does sand become mixed with it, but other substances, such as gypsum, which dissolve in sea-water, just as salt itself does, are left behind with the salt when the water evaporates. Moreover, in a cold, wet climate like ours, evaporation goes on very slowly, and it would take a long time to make even a small quantity of salt in this way. The salt, being small in quantity and difficult to make, would also be costly. Fortunately for us, we have readier and better means of obtaining salt than by allowing sea-water to be evaporated by the heat of the sun.

In England, and in many other countries too, there are large masses of salt buried like stone in the ground. This salt, which is distinguished as rock-salt, is hard like stone, and very much resembles a brown sugar

candy. It is taken out of the earth by means of mines, which are very similar to coal-mines, and are worked in a similar way. But as salt readily dissolves in water, or crumbles in damp air, great care has to be taken not to trust to the rock-salt for firm supports and foundations, as if it were firm, hard stone. On the other hand, rock-salt mines are generally free from fire-damp, and there is not the great risk of explosions which there is in most coal-mines.

Rock-salt is often given for cattle to lick, and it is used in many industrial operations, but it does not supply our tables. The salt which we eat, or use in cooking, is obtained in a different way, but it is really derived from rock-salt, though in a rather indirect manner. In the same districts where rock-salt is found, many of the springs which bubble up from the ground are exceedingly salt, much more so that any sea water. If a well be made in these districts, the water which is drawn from it is not fresh, but strongly salt. The explanation of this peculiarity is that the water of the spring or well has passed through or rested upon a bed of buried rock-salt, and has dissolved and carried away with it much of the salt. Nature has, in fact, turned the fresh water into strong brine.

It is from brine drawn from wells that our best table-salt is obtained by evaporation, the brine being chosen because it contains a very large proportion of salt and very few impurities. The water of a good brine-well may have dissolved in it eight or ten times as much salt as the same quantity of sea-water. The brine is evaporated by the heat of a fire or of steam, and therefore the work goes on quickly, and is independent of the sun.

The brine is pumped from the wells into large reservoirs, from which it is permitted to flow into iron evaporating pans, which have coal fires beneath them, and sometimes steam-pipes within the pans themselves. As the water evaporates, little crystals of salt form on the surface, and, after skimming about for a little time, fall to the bottom of the pan. From time to time, perhaps two or three times a day, the salt at the bottom of the pan is raked to the side, taken out, and thrown into moulds, or tubs, of the size and shape of the blocks of salt which we commonly see in shops. The moulds, filled with the wet salt, are left on the edge of the pan to drain, and in about half-an-hour the salt is sufficiently set to be turned out of the mould. It is carried to a kind of stove or kiln, formed between the evaporating pan

and the chimneys of the fires, and there it remains until it is thoroughly dry and hard. From the stove it is carried to a slightly heated store-room, and it is then ready for sale.

As the brine in the evaporating pan evaporates, new supplies are admitted from the reservoirs, which are filled by the pumps. The pans are never allowed to become dry, but as the salt settles, it is raked out, and as the water boils down, more brine is turned in. In this way the work is kept always going, and there is no waste of fire, nor any injury done by the fire burning or melting a dry pan. By increasing or diminishing the fires, the work can be made to go on quickly or slowly, and the nature of the salt can be modified in this way. Fine salt is made quickly, while large-grained salt, such as is used on fishing smacks, is made very slowly, so as to permit the salt to gather into small lumps or scales.

HOW COAL IS OBTAINED.

COAL is found in the ground, by the side of earth, clay and stones, and it is dug out with the aid of shovel and pick, just as sand or stone is. At first sight it appears to be a sort of stone, but the fact that it will burn with as much flame and heat as firewood, distinguishes it from all kinds of stone, none of which will burn in the same way. Careful study has shown that coal is only a modified kind of wood, and is, in fact, more or less impure charcoal.

Coal is not found in large masses like building stone, but in thin layers or beds wedged in between other layers of clay, like the meat between the slices of bread in a sandwich. These coal-beds are in some places only an inch or two thick, while at others they are several feet deep. They often spread out over many miles of surface.

Usually there are several bands of coal, lying one above another, with thicker beds of clay and stone between them, like sandwiches piled on the top of each other. This arrangement makes it impossible to dig coal out by means of an open quarry, as building stones are obtained, because the workmen would have to dig out far more useless clay than good coal.

Occasionally, the edge of a bed of coal will show itself on the surface of the ground. When that happens, the collier digs the coal out from the edge, and props up the clay above with wooden posts, to prevent it falling upon him and burying him up. I have no doubt that this was the first kind of coal-mining that was ever practised.

As a rule, however, coal-beds are found below the surface of the ground, and quite hidden by the soil above them. Sometimes they are so near the surface that workmen dig into them when they are making cellars, or wells. In many places where coal is found near the surface, it used to be dug out in a very simple way. The workmen made a round hole, like a well, into the ground, until they reached the bed of coal. Having dug out the coal at the bottom of this hole, they removed as much of the coal as they could on every side, undermining the clay

above as they did so. When the upper part of the hole showed signs of falling in, they abandoned that pit, and commenced another in a different place. As these holes were wide at the bottom and narrow at the top, they were called, from their shape, "bell-pits." After a time the workmen learned how to strengthen these pits with wooden supports, so as to prevent their falling in; and were able to draw out more and more coal before they abandoned them. In this way the science of coal-mining was developed, until we now have mines of incredible depth and size.

As coal is not found everywhere, much careful observation is made in order to discover whether there is any probability of coal being found in the ground where it is proposed to make a pit. If the position selected appears to be favourable, a trial of the ground is usually made, before the pit itself is commenced. This trial consists in slowly boring into the ground a small hole a few inches wide, and observing, by the fragments which are brought up by the borer, what kind of soil or rock it is passing through.

If the borer shows that there are good beds of coal lying in the ground below, the next operation is to make a pit-shaft from

the surface of the ground to the bed or beds of coal which are to be dug out. The pit-shaft when completed, is like an exceedingly long chimney, buried in the ground. It is dug out little by little, and in order to prevent the sides of the shaft from falling in, and so closing up, it is cased with wood, stone, brick, or iron. This casing is put together in stages from the top downwards. When the shaft has been dug out for some distance, strong timbers are driven into the sides, and a portion of the case is built up upon them. The workmen dig on, and by-and-by they put in other timbers, and build up another stage of the case, carrying it up until it reaches and supports the first stage. In this way they continue on, until the whole shaft is made, like a chimney built from top to bottom.

Having reached the coal, the miners begin to cut tunnels, or galleries, into it in various directions, with the aid of their picks and shovels. The coal which is dug out of these galleries is shovelled into little trucks, which are wheeled to the shaft, and placed in a kind of cage or car. To the top of the cage a strong wire rope is attached, which passes up the shaft and over a great wheel to a large roller or drum, upon which the other end of the rope is wound. A steam engine

is so arranged that it can be made to turn this drum either way, and thus it raises or lowers the cage and its contents as required. There are, in fact, two cages to each pit-shaft, and their ropes are so wound upon the drum in opposite directions that one cage comes up while the other descends. The miners also go to their work in these cages, and return in them when work is over.

As the miners cut the galleries into the coal in various directions, they are careful to leave sufficient coal standing to support the roof of the mine. The roofs of the galleries are generally supported by planks and wooden pillars, and often the sides, and even the floors, are protected in the same way. If the galleries are long, iron rails are laid down for the trucks of coal to run upon. These trucks are drawn along by boys, or horses, or engines, according the size or importance of the pit.

At the end of the galleries the miners dig at the coal with their picks and shovels. If the bed is very thin, they have often to crouch down, or even lie down, in order to reach it. The owners of the pit want as much coal and as little clay as possible, because the clay is only rubbish to them, and any labour spent in moving it to and fro

is wasted. If the bed of coal is thick and hard, it is often broken up by blasting it with gunpowder or some other explosive.

Much water finds its way into most coal-mines, just as it does into quarries. This water runs along the various galleries until it reaches the lowest. A well is usually sunk in the lowest part of the pit, and a shaft is opened above it. A powerful pump, worked by a steam engine, draws the water from the well, and pours it out on the surface of the ground. But for this pump, it would often be quite impossible for the miners to work in the pit at all, because it would fill with water.

One great difficulty in the working of mines is to keep the miners supplied with air. If several shafts are made in different parts of a mine, there is nearly always a natural current of air down some of the shafts, through the galleries, and up the other shafts. If this does not give a sufficient supply of air, a large fire is made and kept burning at the bottom of one of the shafts. This draws the air from the mine, and sends it up the shaft, as up a chimney, while fresh air flows down the other shafts to supply its place. Occasionally a pump, worked by steam, is used to force air into the mine.

The miner usually carries a lamp with him to light him on his way and at his work. At one time, candles and ordinary lamps were used, but now their use is forbidden. In most mines there is a certain amount of a gas called *fire-damp*, which is very explosive when set on fire by a naked light. For a long time miners knew of no way of avoiding the terrible explosions caused by fire-damp, which often killed many men. About ninety years ago, Sir Humphrey Davy and George Stephenson each invented safety lamps, which were practically safe in mines, and are now used in all of them. The flame in these lamps is really enclosed in a roll of fine wire netting, and this is found to be sufficient to prevent the flame from lighting any gas outside the lamp.

HOW FLOUR IS MADE.

WE all are familiar with the sight of fields of waving corn, gleaming in the bright sunlight, and giving golden touches to the beautiful landscape. Few of us, perhaps, think of the farmer's anxiety for these ripening crops, upon which his success depends so much ; and still less do we think that our flour or our bread will be less plentiful if the harvest is a failure, although we know that flour can only be obtained from the wheat which is growing in the fields. Our grandfathers, who depended almost entirely for their flour upon wheat grown in England, were much more interested in the corn fields and the harvest than we usually are.

Before the growing corn is converted into flour much labour must be given to it. It has first to be reaped. In days gone by,

reapers cut the corn with their bent sickles, but now this work is nearly always performed by a reaping-machine. This machine is a kind of cart, with a long bar projecting from one side of it near the ground. Upon this bar there are a number of sharpened points projecting forward, and a similar bar, having similar points, is laid upon the top of it. As the cart moves forward, the upper bar slides to and fro over the lower one, and the points upon it cross those upon the lower one like the blades of so many scissors, and thus they cut through the stalks of the standing corn. At the same time a sort of light paddle-wheel, turning among the ears, beats the cut corn upon an endless band, which carries it into the cart, where it is bound into sheaves and tossed out at the other side. The reaping-machine is drawn by horses, and it does the work of many reapers quickly and well.

The sheaves which the machine has bound are gathered into carts and carried to the farm, where they are stacked or stowed away to await the next operation, which is threshing. The object of this is to knock the grains of corn from the straw and chaff. It used to be done by giving the corn a real thrashing, or beating, with jointed rods, called flails. Now, however, the farmer hires a threshing-machine to do the work. The

threshing-machine is brought to the farm by a traction-engine, and when it is at work it is driven by a leather belt from the same engine. The corn is thrown into one end of the threshing-machine, and passes through rollers or beaters, which tear out the grain from the straw and the husk. The grain falls through a sieve, which keeps back the straw, while a revolving fan blows away the chaff and the dust. The grain passes down a spout and is caught in a sack, while the empty straw is tossed out at the side of the machine.

The next operation in the manufacture of flour is the grinding of the grains of wheat. At the present time the farmer sells his corn in sacks to a miller, who grinds it, and then sells the flour at a profit. But at one time many people ground their own flour at home, very much as they now grind their own coffee, though the flour-grinding was a much harder and longer operation than coffee-grinding.

The readiest way of breaking wheat-grains into flour is to pound them between stones, and some of the savage people of various countries make all their flour in this way. The English had, however, improved upon this method a thousand years and more ago. They used a grinding mill, or *quern*, of stone,

which could be turned by hand. The *quern* consisted of two rough, flat stones, like thin cheeses, one of which was laid upon the top of the other. A rather large hole was cut through the centre of the upper stone, and a large peg, or handle, was stuck into a small hole in the side of the stone, or on the top near the side. The corn to be ground was poured into the large hole in the centre of the upper stone, and this stone was then turned round by means of its handle. The corn passed in between the upper and the lower stones, and was ground by the rough surfaces rubbing against each other. It came out as flour all round the edge of the *quern*, and a cloth was spread under the *quern* to catch it.

The flour obtained from querns was not very white, because the brown skin of the wheat grain was ground up with the white flour within. The particles of skin were sometimes removed by passing the flour through a fine sieve, which retained the skin while it allowed the flour to pass through.

If we look into any old water-mill or windmill where flour is made, we shall find that the work which is there going on is very similar to that which I have just described. The grindstones are as large as cartwheels, and, being boxed in, they look like the tops

of large barrels projecting through the floor. If, however, we removed their cases, we should find the stones were flat and thin, and that they were arranged exactly like the stones of a *quern*. The upper one is turned round by suitable machinery, put in motion by the water-mill or the sails of the mill. The wheat falls from a hopper into the hole in the upper stone, and, after being ground, it passes through the floor, and is delivered by a spout into sacks placed in the story or cellar below. The flour may be sifted through a muslin or silk sieve at the same time, the sieve being moved from side to side by machinery.

The upper millstone in one of these mills does not touch the lower millstone, but turns upon a pin, which keeps it very near the lower stone, without allowing it to touch. How close the stones are to each other you will be able to imagine, when you think how finely the flour is ground, and when you remember that nothing but flour escapes from the stones. If the stones touch each other they immediately strike fire, and the flour is burnt. From this you will understand that the stones have to be very carefully selected and cut, and they are consequently very costly.

Until a few years ago all our English flour

was ground by flat millstones. But a new method of grinding flour by means of rollers has now become well established, and the flour obtained in this way is much whiter than the flour obtained in the old way, though it is probably not so good as a food. The roller mills are fitted with pairs of steel rollers, which have spiral ridges upon them. These ridges are so arranged that they cut or scrape off the outer parts of the grain, and leave only the very whitest part to be ground to flour. The flour passes through, perhaps, as many as twenty rollers before it is delivered to the dressing-machines, which separate all the husk and inferior portions of the grain from the pure white flour by means of silk screens.

HOW A STAINED GLASS WINDOW IS MADE.

WE are all aware that when iron is exposed for some time to warm, damp air, it rusts. This rust is something quite different from the iron itself. It is soft and crumbling, and its colour is red or brown, while that of polished or clean iron is greyish, or white and glittering. A teacher of chemistry would tell us that the rust was really a combination of a portion of the iron with some of the oxygen which forms a great part of the air we breathe; and perhaps he would also tell us that its scientific name was oxide of iron.

Rust is, however, only one oxide of iron selected from several. The fiery sparks or scales which fly about when a blacksmith is hammering a piece of red-hot iron are another form of oxide of iron. When they

are cool, they are little, blackish flakes, quite different in appearance from rust. Yet they are nothing but a combination of iron and oxygen, like the rust, the difference being that the scales contain a little more in proportion of the oxygen. So, too, there are oxides of other metals, such as copper, gold, silver, chromium, and others, the names of which, perhaps, you never heard before ; and all these oxides differ from each other in their appearance and properties. Some, like rust, are easily obtained, while others are comparatively rare.

We have already seen how glass is made by melting together sand, lime, and potash or soda. If we wish to learn how a window is made of stained or coloured glass, we must next discover how the glass itself is coloured. Coloured glass is obtained by melting, with the other materials of which the glass is made, various metallic oxides, such as those which I have just described. Each oxide imparts a distinct colour to the glass, and by using more or less of the proper oxide, and by blending the oxides in various ways, every tint of glass may be produced. Remembering that it is always the oxide, and not the pure metal, which tints the glass, we may say that iron gives a green or brownish-yellow colour, according to the particular

oxide which is used ; copper, a red or green colour, in the same way ; manganese, a purple or black ; chromium, a green ; gold, a pink or ruby ; and cobalt, a blue. Iron oxide is nearly always present in the sand which is used in making common glass, and this is the reason that common bottles have usually a greenish tinge.

A glass-blower can, or course, make any of these coloured glasses into bottles, jugs, bowls, dishes, or sheets, just as if they were ordinary colourless glass. There is one very clever little trick, as it were, which is often practised, and is worth describing. The glass-blower who is making some ornamental glass object, dips his blow-pipe first into a pot of melted colourless glass, and next into a pot of coloured glass, ruby, we will suppose. He blows through his pipe, and makes the bowl, or whatever it may be, in the usual way. When it is finished, it appears to be made of ruby glass entirely, but really it is a white or colourless bowl with a ruby covering on the outer side. If, now, it be passed on to a glass-cutter to be ornamented, he will cut stars and other patterns on the outer side of the glass, and in doing so he cuts through the ruby glass in these places, and leaves the clear glass bare. The effect is very pretty, for the bowl has now a ruby

ground, with a cut pattern of clear, uncoloured glass.

When a stained glass window is required for a church, an artist prepares one or two coloured designs, which represent the appearance which the window will have when it is finished. One of these designs having been selected, a copy of it is made, as large as the finished work is to be, which will, of course, depend upon the size of the window. Upon this copy all the patches of different colour are clearly outlined with a number of lines, which form a rough network over the picture. The copy is laid upon a table and securely fastened, and a workman goes carefully over it, patch by patch, selecting pieces of glass corresponding in shade to the colour of each patch, and cutting them to the shape of the patch. When he has completed this part of his work, he has before him a sort of puzzle-picture in coloured glass, which is a rough copy of the pattern upon the table.

In the painted pattern, however, there are many details, such as the features of faces, and various kinds of ornamentation, which have to be drawn or outlined with lines, and these cannot possibly be copied in separate pieces of glass. The window-maker must contrive to paint these upon the glass in some such way as they are painted on the

paper itself, and he must also contrive to fix his colours on the glass, so that they will not wash off or wear off.

To effect this, he takes some powdered glass and mixes with it some substance, such as borax or red lead, which will make the glass melt at a much lower temperature than that which would be necessary to melt the glass itself. To the powdered glass and the borax or red lead he adds some oxide of iron, which, as I have already said, gives a brownish colour to melted glass. He has then a mixture of glass and other things, which will melt with a little heat and turn brown. To these mixed powders he adds a little gum-water, and he has then a kind of paint with which to paint his glass picture. Suppose that he wishes to paint the eyes and other features of a face. He takes the glass which he has cut for the face, and, laying it on the copy, he paints over the lines which he sees through the glass. Occasionally, perhaps, he places the glass on an easel, to see if it gives the proper effect when the light shines through it.

When all the pieces which require painting are finished, they are placed upon shelves in a kind of iron oven, called a muffle. The shelves are covered with powdered chalk, so that the glass may not touch the iron, and

the painted sides of the glass are turned upwards. The muffle is closed, and the flames of a fire are allowed to play around it. The pieces of glass in the muffle become hot, not sufficiently hot to melt. The paint, however, upon the surface of them, owing to the borax or red lead, does melt, and changes into glass, which the oxide of iron tinges brown. As soon as the paint turns into glass, the fire is raked out, and the pieces in the muffle are allowed to cool slowly. When they are cold, the glass from the paint is firmly joined to the glass of the piece, and is, in fact, part of it.

It only remains now to put the pieces in their proper places again over the pattern, and join them all together. This is done with strips of lead, which have a deep channel on each side. The edges of the pieces of glass fit into the channels, and the leaves at the top and bottom of the strip fold over to hold them in their places. The strips pass in and out round all the pieces, and they are fastened with melted lead or solder at the joints, where they meet or touch. Lastly, the whole window is made water-tight by scrubbing it with a cement of white lead, oil, and plaster of paris, which fills up all the interstices.

HOW A HORSE-SHOE IS MADE.

IN large towns, where many horses are at work in the streets, there are farriers or blacksmiths who do nothing else but make horse-shoes, and fasten them on to the horses' hoofs; but as a rule the shoeing of horses occupies only a part of the blacksmith's time, and the rest of it is devoted to all kinds of working in wrought iron. The blacksmith has nothing to do with cast iron. He gives all his thought and labour to wrought or malleable iron, which he bends and shapes to the form which he requires with the help of his hammers only. He has indeed other tools, but all those which are used in giving shape to the iron are simply aids to the hammer, and might be regarded as hammers of peculiar forms.

If we peep through the open door of any smithy, we may see the blacksmith at work.

Let us first, however, take stock of the smithy itself and the tools which the smith uses. There is a fire, or forge, in which he heats his iron, in order to make it softer and easier to work. By the side of the forge there is a huge bellows to blow the fire, and in front of it is the anvil upon which all the hammering is done. On the ground around are hammers of various sizes, from the heavy sledge, which is swung with both arms, to the small hand-hammer, which is light as a toy in the strong hand of the smith. Near the anvil there is a small tank of water into which the smith dips his hot iron when he wishes to cool it quickly. On the wall by the forge or lying about in various directions are iron tongs, chisels, pinches, and dies of many kinds, while sheets and rods of iron are piled in the corners of the smithy or against the walls.

The bellows used by blacksmiths are of various shapes. Some resemble the small bellows which we use for blowing our kitchen fires, while others are tall and circular like a concertina placed on end. They are very large, and they are worked by a long handle, which, when it is pulled down, pushes the ends of the bellows together, and drives out the air through a pipe into the fire. When the handle of the bellows is allowed to rise,

the heavy wooden bottom of the bellows falls down, and a small valve or trap-door placed in the bottom opens upwards to let in more air, so that the bellows are filled again. When the bellows close, this valve shuts down, and thus prevents the air from escaping by any other way but the pipe. If you carefully examine a pair of kitchen bellows, you will soon pick out how they work; and blacksmith's bellows are usually very similar in their construction and use.

The blacksmith's anvil is a heavy block of wrought iron, which is fixed to the top of a wooden base, buried in the ground. The anvil itself is a kind of short, stout pillar, widening out at the top to a small oblong table, at one end of which there is a strong conical beak somewhat like a pig's snout. The other end of this little table is cut away underneath like the stern of a ship, and a small square hole is cut vertically through this part like the hole through which the top of the rudder projects in a yacht.

Now, having learned so much about the blacksmith's forge, bellows, anvil, and tools, let us see what use he makes of them. As a rule two men work at each anvil, one of whom is a blacksmith, and the other an assistant, who is commonly called a "striker" in the North of England. The blacksmith who is

about to make a horse-shoe takes a rod of wrought iron, which is about an inch wide and half-an-inch or three-quarters of an inch thick. He pokes the end of the rod into the forge, and the striker blows the bellows until the end of the rod is white hot. The blacksmith then draws out the rod, and, holding it in his left hand, lays the end of it across the top of the anvil, and with the aid of a steel rule measures off a suitable length for the shoe. He takes up one of his chisels, and lays the edge of it across the rod at the point where he wishes to cut off the piece which is to form the shoe. The chisel is a kind of axe and hammer-head combined, and it is fixed in a handle made of bent iron or a bent wooden wand. While the smith holds the blade across the iron rod with his right hand, the striker gives a few blows with his heavy sledge upon the hammer-head at the back of the chisel, and the red-hot iron is quickly chopped off the rod.

Laying the rod aside, the smith takes up the short piece with his iron tongs, and puts it in the fire. When it is hot enough for his purpose, he draws it out again, and, holding it on the anvil, begins to flatten it with a small hammer, while the striker hammers away with him. Each delivers a blow in turn. At first sight it seems rather ridiculous for

the smith to put in his blows at all, for they appear to have no effect in comparison with the blows of the sledge-hammer. But if you watch carefully, you will see that the smith with his small hammer is simply showing the striker where to deliver his blows, and when the little hammer stops, the striker lays down his sledge.

When the iron is flattened out to the proper degree, it is returned to the fire, and when it is once more hot, the smith takes it out, and, holding it across the point of the anvil, he begins to bend it into horse-shoe shape by hammering the ends round the anvil's point. If the shoe is to be a small one, it is shaped nearer the extreme point, while if it is to be a large one, it is bent nearer to the body of the anvil, where the beak is further round.

Little by little the shoe is hammered to the proper shape, and then a groove is cut along the under side of it by means of a chisel somewhat like that which was used for cutting off the piece from the rod. The holes for the nails are made in a similar way, the red-hot shoe being laid over the hole in the anvil, while the point of a punch is hammered through it. If the shoe is intended for a heavy cart-horse working in streets paved with hard and slippery stones,

the ends of the shoe are turned down so as to form broad, flat spikes. This is accomplished by laying the shoe on the anvil with the ends projecting over the side, and hammering them down over the edge of the anvil until they are bent at right angles. Many horses have peculiarities in their walk which necessitate special alterations in the shoes which are made for them. Sometimes pieces of steel are welded to that part of the shoe which wears away quickest. This welding is accomplished by heating the two pieces of metal, and hammering them together until they unite into one piece in which no joining can be traced. The steel being harder than the iron is not so quickly worn away.

When a horse is to be shod, the old shoes are knocked off, the nails are taken out, and the hoof is carefully pared flat to receive the new shoe. This is fitted to the hoof, and fastened on with nails driven into the hoof itself. The hoof is without sensation, and the horse feels no pain unless the nails are too long, and reach the flesh at the root of the hoof. The holes in the shoe are somewhat funnel-shaped, with the wider end under the shoe, and the heads of the nails are made to fit them exactly, and to lie deep in the groove of the shoe. In consequence

of this the nails do not begin to wear until the edges of the shoe on each side of the groove are worn down ; and even when they do begin to wear, so long as there remains a little of the wider part of the head which will not pass through the narrow end of the hole in the shoe, the latter is held fast on the hoof.

HOW SUGAR IS MADE.

SUGAR is obtained from the sugar-cane, the beet, the sugar maple, and one or two other plants. As most of our English sugar is got from the sugar-cane, we will confine ourselves to that plant. The sugar-cane is really a gigantic grass, nearly two inches thick, and attaining to an height of from six to twenty feet. It grows in many tropical countries, but it is most cultivated in Cuba, Mauritius, Brazil, British Guiana, Barbadoes, and most of the West Indian islands.

The stalk of the sugar-cane has a very hard case, but the inside is juicy, and the juice is sweet—so sweet, in fact, that some savages, who do not know how to make sugar, grow the cane for chewing. This juice, when it is squeezed out of the cane, is green, and very like the juice of grass.

In describing how salt is made, I have already said that sugar can be dissolved in water, and that when the water is evaporated the sugar is left behind. As the water containing the sugar disappears in vapour, little specks of sugar begin to form in the water which is left, and sink to the bottom of the pan. If the evaporation goes on very slowly, these specks of sugar grow in size until they are fairly large pieces. When carefully examined, they are found to have rather regular and symmetrical shapes, like so many little diamonds or bricks. A number of substances have this tendency to form themselves into special and regular shapes, and we express this change by saying that they *crystallise* or form *crystals*. It is not often that the crystals are perfect. They are nearly always broken off short at some point, or joined together with other crystals in ways which mar their perfect shape. We have good examples of sugar crystals in a piece of candy, which is nearly pure sugar in large crystals, which have been formed round a string by a very slow evaporation. Smaller crystals, and less perfect ones, may be seen in any lump of sugar, especially with the aid of a microscope. Occasionally, too, treacle, which is little else but sugar and water, will turn sugary—that is to say,

crystals of sugar form themselves out of the sugar dissolved in the water.

Now, perhaps, you will be asking yourselves what is my object in telling you all this about crystals. A crystal of any kind is remarkably pure, and the sugar-maker relies very much upon this operation of crystallising, in order to purify his sugar. Boiling, filtering, and crystallising are the chief operations in the making of sugar. The boiling of water containing sugar has to be performed very carefully, however, because a very little heat given to the sugar itself, melts it, and burns it brown, as every toffee-maker knows.

The first stage of sugar-making is performed by the cane itself, which makes the sugary juice as it grows, and stores it up as food to assist its future growth. When the canes are ripe, they are cut down close to the ground, cut into lengths, and carried immediately to a mill, where the juice is squeezed out of them by means of heavy rollers. As the juice will not keep fresh for more than half-hour, the converting of it into sugar must be commenced at once. It is placed in a pan and warmed, while a "cream," or mixture of lime and water, is added to it. The green juice immediately turns yellow, and a thick scum, somewhat

like the white of an egg, rises to the surface, and is skimmed off.

The juice is next transferred to a row of copper pans of different sizes, arranged in order, the largest at one end, the smallest at the other. These pans are heated by a fire, which is often fed by the crushed canes. The juice is poured into the largest pan, and as it thickens with evaporation, it is transferred from pan to pan, until it reaches the last. From this it is turned out into a wooden vessel, called a *cooler*, in which it begins to crystallise, which means, you will remember, that little crystals of sugar begin to form in the juice. When the crystallising is completed, the contents of the cooler are placed in barrels standing over a tank. The bottom of each barrel has openings in it, which are roughly covered with plantain leaves, and these act as strainers, allowing the juice or *molasses*, of the sugar to pass through into the tank, but retaining the crystals in the barrel. The sugar which remains in the barrel, when the molasses have drained away, is known as raw sugar. It is not very pure, because it has not been carefully drained, and, in fact, the whole of the processes through which it has passed have been rough and imperfect. The raw sugar is such sugar as can be made with the

imperfect machinery of the countries where the cane is grown, and it has to be sent to England to be refined. What we usually call sugar-making in England is simply the refining of raw sugar.

The refining commences at the top of a many-storied building, where there is a large tank of water with a steam-pipe in it. The raw sugar is shovelled into the water, and dissolves, while a jet of steam passing through the water makes it hot. A scum rises to the surface, and is skimmed off, but the bulk of the impurities are got rid of by careful filtering. The first filter is made of a number of cotton bags, shaped like pillow. cases, but very much longer. The mouth of each bag is tied over the wide end of a funnel, the smaller end of which is screwed into the bottom of a tank. The dissolved sugar from the steam-tank flows into this filter tank, and passes through the funnels into the filter-bags, which are hanging like so many barnacles in a case. As the lower end of each bag is closed, the sugar-water must pass through the interstices of the cloth, and in this way it is partially filtered. To filter it more completely it is made to pass through large tanks, which are nearly filled with charcoal obtained from burnt bones. It comes out of the bottom of these

tanks as clear as water when the charcoal is fresh, but after a time the charcoal loses its efficiency, and has to be re-burnt before it can be used again.

The next operation is to make the sugar crystallise out of the filtered liquid, by boiling it down, and then allowing it to cool. But as too much heat burns the sugar, and makes it brown, means are adopted to make the liquid boil at a lower temperature than is usual. It has been discovered that water boils at a lower temperature when the pressure of the air is less, and at a higher temperature when the pressure is heavier. The sugar-maker boils the filtered liquid in closed pans, from which he draws out the air by means of a pump, and in this way he is able to evaporate the water with only a little more than half the heat which is usually required to boil water in an open vessel. The liquid, after being sufficiently boiled down, is passed into another pan to crystallise, and it is then placed in a number of iron moulds, which will give the sugar the shape of the pointed loaves which we see in the shops. The moulds are placed point downwards, and any liquid which remains in the sugar drains out through a hole in the point. After a few days the sugar is knocked

out of the mould, trimmed to a neat shape, and dried in a heated room. It is then ready for sale. The syrup which drains from the moulds is treacle.

HOW CANDLES ARE MADE.

EVERY candle has two parts which we can clearly distinguish—the wick, and the tallow or wax. The wick is usually made of twisted or plaited cotton fibres. The wax varies in composition a good deal, but it is always some kind of fat or oily wax which melts and burns easily. At the present time the wax most commonly used is largely composed of paraffin.

When a light is put to the wick of a candle, the wick is set on fire. As it burns, it melts the wax near it, and this is drawn up by the wick and turned into gas by the heat of the burning wick. This candle-gas, as we may call it, feeds the flame, and makes the bright candle-light. We can easily prove that there is a candle-gas, because, if we blow out a candle, and quickly bring a lighted match near it while

it is still hot, we can re-light the candle without touching the wick. The gas rising from the candle takes fire before the lighted match touches the candle itself.

At the present time candles are made by machinery, and great pains are taken to prepare a suitable kind of wax and a wick of the proper size and shape. Seventy or eighty years ago, however, people often made their own candles at home, using the simplest of materials. If we begin by finding out what they did, we shall be better able to understand how candles are now made.

The Rev. Gilbert White, who wrote the *Natural History of Selborne* more than a hundred years ago, gives an interesting description of the manner in which the villagers of Selborne made rush-lights, which were really a poor kind of candle. They cut a certain kind of rush which grew by the side of streams, and after steeping it in water, they stripped it of nearly all its peel or rind, leaving only a narrow rib from top to bottom to support the pith of the rush. The piths of a number of rushes prepared in this way were laid upon the grass to bleach, and were then carefully dried in the sun. Meanwhile, the cottager collected all the scraps of meat fat, bacon,

and grease of every kind, and boiled them down to liquid tallow, sometimes adding a little bee's-wax from the hives, when he could afford to do so. Taking the dried rushes in his hands, he dipped them in the melted fat, and drew them out when they had received a covering of the tallow. When the tallow had cooled and set, the rush-light was ready for use. It was lighted like a candle, and burned in the same way, the rush serving as a wick. A good rush was nearly two and a half feet long, and burned about an hour.

The commonest tallow candles were made in nearly the same way as the rush-lights, but they had a wick of loosely twisted cotton. The cotton was cut into lengths about twice as long as the candle was to be. Each length was doubled, and the ends were twisted round each other for a certain distance, leaving a loop where the wick was folded. A number of wicks were hung upon a rod by these loops, and the candle-maker, holding the rod in his hands, dipped the hanging wicks into a vat of melted tallow. When the wicks had received a proper covering of the tallow, the rod was suspended upon a frame, and the candles were left to cool and dry. After a time the rod was taken down, and the candles were

dipped again in the same way; and thus the alternate dipping and drying were continued until the candles attained their proper size and weight. When the candle-maker wished to make a great many candles at one time, he joined a number of rods, in a kind of frame, and dipped them all at once. As this frame was very heavy to move about, he suspended it to a rope, which passed over a pulley, and was weighted with a scale-pan and weights at the other end. As the candles grew heavier with the tallow which they took up, the weights in the scale-pan were increased so as to maintain a true balance. Some kinds of wax candles cannot be made by dipping, as the wicks will not take the melted wax properly. Many of these are made by pouring melted wax down the wicks as they hang over a trough of wax. The wicks are, in fact, basted with melted wax, until a sufficient quantity adheres to the wick to make a candle. When these basted candles are sufficiently cooled, they are rolled upon a smooth table by means of a board to give them a true cylindrical shape.

There is one other way of making candles without machinery, and that is by moulding. The candle mould is usually made of pewter, and is the same shape as the candle itself.

A number of moulds are placed point downwards in a wooden frame, the upper part of which forms a shallow trough. The wider, open ends of the candle-moulds are fitted into the bottom of the trough, so that any melted tallow or wax poured into the trough runs into the moulds. In the point at the bottom of each mould there is a small hole, and through this hole the wick of the candle is passed, drawn up the mould, and fastened in such a way as to remain in the centre of the mould. When these preparations have been made, melted wax or tallow is poured into the trough of the frame, and runs down into each mould and surrounds the wick. The frame and moulds are then laid aside to cool, and when the candles are set, the superfluous tallow or wax is removed from the trough, and the candles are drawn from their moulds, the wicks coming out with them.

A very short description will give you some idea of the way in which candles are made by machinery. At the bottom of the candle-making machine there is a frame of moulds very similar to that which I have just described, and there is also some mechanism by which the candles, when they are made, may be pushed up out of their moulds. The wick for each mould is

drawn from a reel under the point of the mould. When one set of candles is made, they are pushed out of the moulds, and as each candle moves upwards, it draws off a new supply of wick, and pulls it up into the mould, as a moving rocket carries its stick. The moment the finished candle leaves its mould, it is seized and held by a clamp above. There it remains, keeping the wick below it steady in the middle of the mould, while a new supply of wax is poured in, and sets into a candle. The wick is then cut off immediately below the first-made candle, which is taken out of the machine completed. Another turn of a handle forces the new candles out of their moulds, and each is seized and held until another set is made. Thus the work goes on, one set of candles being always held by the machine, while another set is being moulded.

HOW CLOTH IS MADE.

YOU have often seen a woman darning stockings, but perhaps you have never thought that she was making cloth. And yet that is just what she is doing, as I will try to show you. She is closing the hole in the stocking with a little piece of worsted cloth, which she is making with her needle and thread as she goes along. Let us watch her carefully and see how she does it.

Taking a long thread in her needle, she passes it through the stocking near one edge of the hole, then carries it across the hole, passes it through the opposite edge, and comes back again in the same way. Thread after thread is stretched across the hole in this way, all neatly placed side by side, until there is no room for any more. Then the woman begins at one side, and places thread after thread across the hole. She passes each

cross-thread in and out of the first threads as she comes to them, one by one, going over the first one, under the second, over the third, under the fourth, over the fifth, under the sixth, and so on. When she comes back across the hole with the next thread, she is careful to go over those threads which she went under before, and under those which she went over before. In this way she makes a sort of little lattice-work of worsted, or woollen threads, which are all interlaced, or threaded in and out of each other. If, when she has done, we could cut out this little patch of lattice-work without loosening the threads, we should have a little piece of roughly-made cloth.

In some parts of Africa cloth is made in a way which is very much like darning a hole. The cloth-maker has a square frame, somewhat like a picture-frame, but quite plain, across which she stretches a number of threads from top to bottom. Then, commencing at the sides, she interlaces cross-threads, one after another, side by side, until the frame is nearly filled, when she cuts out the darned piece, ties the loose ends of the threads, so that they may not come out, and her cloth is made.

Let us turn now to the north of India, where the women make cloth in a rather

better way. Each woman takes a number of very long threads, and fastens them to heavy wooden rods, one at each end of the threads. She fastens one of these rods to a tree trunk, or an upright post, and then walks away from the tree or post until the threads are stretched tight, when she sits down, and places the other wooden rod in her lap. Taking a little stick upon which some thread is wound, she uses it as a darner uses her needle, and works it in and out of the long threads from side to side, allowing the thread to unroll from the stick as she goes along. When the stick has passed to and fro a great many times, there is a little piece of cloth close to the rod, which lies in her lap. She rolls this cloth round the rod, and moves a little nearer to the tree or post. She goes on in the same way as before, making a little more cloth, which, after a time, is rolled on the rod, and the woman again moves a little nearer to the tree. When at last she reaches the tree, all her long threads are used up, and she has instead a long roll of cloth wrapped round the wooden rod in her lap. She unrolls this cloth, cuts off the rods at each end, and her work is done.

In England, all our cloth is made by machinery. Nearly all the machines, or looms, as they are called, for making, or

weaving, cloth, are now driven by engines, but not very long ago they used to be worked entirely by hand, and were called *hand-looms* on that account. Occasionally, we may still see a hand-loom in use, and I should like to tell you what hand-loom weaving is like. If you understand that, you will not have much difficulty in afterwards understanding weaving by machine-looms, or *power-looms*, as they are called.

A hand-loom looks rather like an old-fashioned bedstead, with wooden posts at the corners. At each end of the bed there is a large roller, stretching from one side of the bed to the other. One of these has a great number of threads rolled upon it, the loose ends of which are carried along the bed, at the place where the mattress usually lies, to the other roller, upon which they are wound after they have been woven into cloth. The two rollers answer to the two rods of the Indian weaver, with the threads stretching from one to the other.

The weaver stands in front of the roller upon which the cloth is to be rolled. He commences weaving by pressing a treadle with his right foot, and we see two screens placed half-way between the rollers, go up and down, moving the threads with them. One of the screens, which we will call the

odd-screen, goes up, and raises half the threads a few inches. The other screen, which we will call the even-screen, goes down, and lowers the remaining threads a few inches. If we numbered all the threads in the loom, we should find that the odd-screen raises the threads 1, 3, 5, 7, 9, and the other odd numbers; while the even-screen lowers threads 2, 4, 6, 8, 10, and so on.

The moment the threads have been set like this, the weaver pulls a kind of skipping-rope handle towards the right, and a little carriage, or shuttle, shoots out of a box on one side of the loom, and runs across to the other side on a little ledge. The shuttle carries a little bobbin of thread, which unwinds as the shuttle runs along, leaving a trail of thread behind it. When we look carefully, we see that the shuttle runs over the top of the threads 2, 4, 6, 8, &c., which are lowered till they rest upon the ledge, and under the threads 1, 3, 5, 7, which are raised. In other words, the shuttle lays a thread under 1, over 2, under 3, over 4, and so on.

When the shuttle has passed, the weaver draws a kind of swinging comb towards him, which combs straight the thread left by the shuttle. Then he presses another treadle with his left foot, and the screens change places. The odd-screen, with its threads,

1, 3, 5, 7, &c., comes down; while the even-screen, with its threads, 2, 4, 6, 8, &c., goes up. The weaver pulls his skipping-rope handle towards the left, and the shuttle runs back along the ledge.

This time it passes over threads, 1, 3, 5, 7, &c., which are down, and under 2, 4, 6, 8, &c., which are up. That is to say, the shuttle-thread is laid over 1, under 2, over 3, under 4, and so on. The weaver pulls his swinging comb towards him, and the new thread is combed close by the side of the thread which was laid before.

The weaver has woven two threads, and all that he has to do is to keep on repeating this, unless some accident happens, such as the breaking off of a thread. When he has woven a little strip of cloth, he rolls it up upon the roller in front of him, and, by so doing, he draws off more thread from the roller at the other end of his loom. When all his thread is used up, his piece of cloth is finished so far as he is concerned. He cuts it away from his rollers, and delivers it to the dyer and other workers, who will prepare it for the tailor.

HOW COAL GAS IS MADE.

I HAVE already told you something about the way in which coal is obtained, and I wish now to explain how the gas which we use for lighting our houses and our streets is made from it. We have all seen coal burning upon our fires, and it will help us more easily to understand how gas is made, if we think for a few minutes of what we have often noticed when the fire is mended with coal.

If we place a small piece of coal upon a bright red fire, the coal crackles and smokes for an instant, and then bursts into flame. If, however, we throw a large shovelful of coal upon a rather small fire, the coal smokes a great deal, but it is a long time before it begins to blaze. If we wish to make the fire burn more quickly, we do not put on more coal, but we take a pair of bellows, and

blow, or pump, air into it; and this has the desired effect. It is quite clear, therefore, that to make the coal blaze or burn, two things are necessary besides the coal itself, namely fire and air. If I had time to draw your attention to a number of other things which you must often have noticed, I should be able to show you that it is only a portion of the air which is really necessary in order that the coal may burn, the rest being of no use in this respect. That part of the air which maintains or feeds a fire has been named *oxygen* by chemists, and it forms only about one-fifth by measure of any given quantity of air.

Returning for a moment to our newly-mended fire, we notice the smoke going up the chimney. If we apply a lighted taper to it, we shall probably see a flame flicker through it for a moment. This shows that there is a gas which will burn rising from the coal. The flame dies out quickly, chiefly because there is not sufficient heat above the coal to keep it burning, and also because there is not sufficient oxygen in the air which has passed through the fire to support the flame.

Now the gas which is rising from the coal upon our newly-mended fires, is the same gas which we use for lighting our rooms. There

is a well-known experiment, which you may have often tried, which shows how easily coal-gas may be made. Take a long-stemmed clay pipe, and fill the bowl with coal-dust. Seal up the top of the bowl with a plug of good clay, which has been squeezed and beaten a little to make it thoroughly plastic, so that it will stick to the pipe-head. When this is done, place the bowl of the pipe in the fire. In a little while it will become hot, and, if the clay does not crack away from the pipe, a little smoke will be seen to puff out of the stem. If a light be applied to this smoke, or gas, it will burn with a bright and steady light, until the supply which the coal will yield is exhausted. If you now take the pipe from the fire, and, when it is cooled, break away the clay from the bowl, you will find in the latter a small black cinder. That is a piece of coke.

In the gasworks of a town, gas is made in a similar way to this, but with appliances specially designed to make as much gas as possible without waste of coal or any of the materials, like coke, which are left behind in the course of the work. But something more is also done. The coal-gas is purified, and it is stored in such a way that every householder may draw his supply just as he requires it.

In the gasworks there is a row of fire-places, over each of which there are one or two iron or clay tubes, or pipes, six or eight feet long, and a foot and a half-wide, set horizontally over the fire, so that they may receive the heat from it. These are called retorts, and they serve the same purpose as the bowl of our tobacco-pipe. The front end of each retort opens above the front of the fire, while the other end, near the flue at the back of the fire, is closed. The open end has a door, and just behind the door there is an upright pipe, which, after rising some distance, bends over into a larger pipe, which runs the whole length of the fire-places, and is called the hydraulic main. These pipes answer to the stem of our tobacco-pipe.

When the fires have been lighted, and have made the retorts hot, the doors of the latter are opened, and coal, broken to the size of a cricket-ball, is thrown in. The retort doors are then closed and made air-tight, and in a short time the gas begins to rise from the coal, and passes up the upright pipes into the hydraulic main.

With the pure coal-gas, however, there rise various impurities and some watery vapour. As these get away from the hot retorts, they cool, and while the vapour condenses into water, some of the impurities

form tar. The tar and water settle in the lower half of the hydraulic main, while the gas rises to the upper half of the main, and passes along to be purified. In order to cool it quickly, it is taken through a number of winding iron pipes, called the condenser, and all the liquid impurities are thus chilled out of it. It is then led to the bottom of a vessel, which bears the name of a scrubber, and is in reality a sort of shower-bath. As the gas rises in the scrubber, it meets sprays of water, which take up any gases which will dissolve in water. Coal-gas itself is scarcely affected by water, and it passes through the scrubber to the next purifier. This is an air-tight vessel, in which there are shelters or trays bearing slaked lime, which removes the last of the impure gases, and leaves the coal-gas sufficiently pure for use.

In every gasworks there are one or more gasometers. These are tall, circular structures surrounded by iron pillars. The former are really tanks of iron turned mouth downwards, and they are supported by chains which pass over wheels at the top of the pillars, and bear weights at their free ends. By increasing the weights, the tank or bell of the gasometer can be raised; and in the same way it may be lowered by decreasing them. The open mouth of each

bell rests in a wide well built of brick or stone, and water is allowed to flow into this well until it surrounds the mouth of the bell and closes it from the outer air.

It is in these gasometers that the gas is stored for use. A pipe from the lime purifier passes through the water in the well, and conveys the purified gas into the tank of the gasometer. The weights supporting the latter are so adjusted as to allow the tank to rest in the water, but as the light gas enters, it bears the tank up, as if it were a balloon, and forces it to the top of the pillars which help to support it by means of the balanced chains.

A second pipe, similar to that which delivers the gas from the lime purifier, leads from the gasometer to the pipes in the streets, which convey the gas to all parts of the town. The weight of the gasometer is always pressing upon the stored gas, and tending to force it out through this pipe, as it cannot return towards the purifiers and retorts. So long as all the gas-taps in all the houses and streets are closed, the gas cannot escape from the gasometer, and the latter remains high in the air; but the moment any gas-tap is opened, there is a little escape, and the weight of the gasometer forces out sufficient of the gas to feed the

flame. As the gas escapes, the gasometer falls, though we do not notice this unless much gas is being used, Thus the gasometer is kept rising and falling, as new gas is made, or the stored-up gas is used.

HOW WIRE IS MADE.

MOST of us have seen wire made of gold, silver, copper, brass, or iron. The operation of wire-making is always the same, no matter what the metal may be; and as we have already learned how iron is made in the blast-furnace, and afterwards puddled and rolled into bars and rods, we will now try to learn how it is made into wire.

As iron wire has to be bent and twisted a good deal, it is made from the best wrought iron. Bars three or four feet long are chosen, and, having first been made red-hot, they are rolled smaller and longer, by passing them between grooved rollers. These rollers, which are only small, are made to turn very rapidly, and the iron is quickly passed through groove after groove, each one of which is smaller than the one before, until at last it is drawn out into a rod about ten yards long, and

perhaps a quarter of an inch thick. It is then ready for the wire-maker, or *wire-drawer*, as he is called, because he draws the rod out into a thin wire.

You will think, perhaps, that the easiest way of drawing out the rod will be to fasten the ends of it in some kind of machine, and then pull them powerfully apart, as children pull at each end of a Christmas cracker. Now this is often done, and it always has one result. The iron rod draws out thin in one place, and breaks into two pieces. This is because the iron, notwithstanding all the care which has been taken in making it, has some parts weaker than others. These weak parts stretch and break, before the rest of the rod is stretched at all, so far as anyone can see. It is found impossible to make wire in this way, and this operation is only used when it is desired to test the strength of an iron rod, and to see how much force must be used before it will break.

Mr. Moffat, a missionary in South Africa, in a book which narrates his experiences, describes how he once saw a native making wire. The story is instructive, because it shows that wire can be made without machinery, and with the help of very few tools. The poor savage came to the missionary one day with a piece of flat iron, and

begged him to make a number of holes of different sizes through it. The plate was nearly half an inch thick, and it took Mr. Moffat a long time to make the holes, which were about twenty in number, and varied in size from the thickness of a slate pencil to the thickness of a thread. When the plate was finished, the black man was delighted, and danced about the village like a man out of his senses, showing the precious plate to everyone. Next day the missionary asked the man to show him what he was going to do with the plate. The savage consented, and set to work at once. He melted some copper in a pot, and poured it into a number of deep holes which he had made with a thin stick in a heap of sand. When the copper had cooled, he had a number of thin, solid bars, which he drew out of the sand. These he hammered on a stone, until they were considerably smaller, when he selected one of them, and rubbed the end of it between two stones until he had made a point on it which was small enough to go through the largest of the holes which Mr. Moffat had made in the iron plate. The savage next stuck in the ground a smooth, round stick, so that it would stand firmly upright. This stick was split at the top, and the black man put the small end of the rod, which he had pushed

through the plate, into this split. Then, while the split held the rod tight like a vice, he dragged at his plate, levering it round and round the stick, until the whole of the rod was drawn through the hole. As the hole was a little smaller than the rod to begin with, the rod was made thinner in passing through it, and it was, at the same time, lengthened. When the savage had drawn the whole of the wire through the first hole in the plate, he took it off the stick, and began in the same way to draw it through the next hole. It was afterwards drawn through the other holes, one by one, becoming each time thinner and longer, until at last it was no thicker than thread.

Now, this is just the way in which iron wire is made in England to-day, with this difference, that the drawing is done by machinery, and is performed more quickly and better. At one end of a long, strong table there is a large iron bobbin placed upright on a rod, which goes through the top of the table, and is made to turn round by wheels driven by an engine. At the other end of the table, there is another upright rod, upon which another bobbin or reel may be placed. This rod is not connected with any machinery, and does not turn round, but it allows the reel which is placed upon it to

turn freely. Between the reel at one end of the table and the iron bobbin at the other, there is a strong plate with holes of different sizes made through it. This plate is held firm by strong upright bars, which are firmly fixed to the table. The holes in the plate are made like little funnels, wider on one side of the plate than the other.

The thin rods of iron, as they come from the forge, where they have been rolled, are placed on a kind of reel, and put on the upright bar at one end of the table. The end of the rod is filed sufficiently small to go through the largest hole of the perforated plate, or drawing-plate, as it is called. On the bobbin, which is turned by machinery, there is a pair of pincers, which can be made to take hold of the end of the rod which has been put through the drawing-plate. When it has seized the rod, the machinery is put in motion, and the iron bobbin begins to turn round, drawing the pincers with it. The pincers draw the iron rod through the hole in the plate, and it gradually unwinds off the reel at the other end of the bench. As the wire passes through the plate it is drawn out thinner and longer. When it is all wound on the bobbin, the machinery is stopped, the coil of wire is taken off the bobbin, placed upon another reel, and is ready to pass

through a smaller hole in the same plate. The operation is repeated again and again, until the wire is as thin as it is required to be.

Wire is drawn without heating the iron. The drawing tends, however, to make the metal hard and stiff, and after passing through the plate a few times, it would quickly break if nothing were done to prevent this. The wire is placed in a closed furnace, or oven, from time to time, and made red-hot. This restores its pliability, and enables the wire-drawer to draw it out a little finer. As often as it shows signs of stiffening, it is placed again in the furnace, and, with care, it can be drawn out as fine as thread.

HOW A COIN IS MADE.

I HAVE before me the picture of some coiners at work in the year 1577. One of them is cutting the coins to the proper size and shape by means of a strong pair of shears. He has in front of him a pair of delicate scales, and one of the pans contains a weight. It is quite evident that he weighs from time to time the coin which he is making, and cuts off little pieces from the edge, until it exactly balances the weight in the other scale. Another man is engaged in making the impression or raised picture which is to be found upon each side of an ordinary coin. At first sight he looks very like a cobbler who is nailing a boot heel. In reality, however, he is striking together two stamps, or dies, and the coin which he is making is between them. These dies are made of hard steel, and the patterns of the

coin are cut into them, just as the hollow patterns are made in the seals which are sometimes hung to watch chains and used for impressing sealing-wax. One die rests with its pattern upwards on the top of a little pillar, which answers to the cobbler's last, while the other is fixed with its pattern downwards in a kind of punch which the coiner holds in his left hand. When the blank piece of metal is placed on the top of the lower die, he lays the upper die and punch upon it, and strikes a powerful blow with his hammer. The metal takes the impressions of the two dies, and becomes a coin. There are other figures in the picture, but I must not stay to describe them now.

Perhaps I need hardly tell you that coins are not made in this simple way now. But until the time of Queen Elizabeth no better way was known. In the church of St. Georges-de-Bocherville, near Rouen, there is a figure carved on one of the capitals which represents a maker of money who is stamping the coins in the very same way that I have described. As this church was built about the time of the Norman Conquest, we see that this manner of coining had been in use for five hundred years with little or no improvement. It is said that a machine for making coins was introduced in the reign of

Elizabeth, but its use was soon given up, and machinery was not used again until about the year 1660.

One of the first and most important machines for coining was the coining-press, which superseded the use of the hammer. There are many kinds of presses which are worked by means of a screw, but the copying-press which is to be seen in nearly every office, will, perhaps, best illustrate the working of the coining-press. The copying-press consists of a stout flat metal plate with an arch or bridge standing over it. Through the top of this iron arch a hole is bored, and on the inner side of this the threads of a screw are cut. A strong steel screw passes through this hole, and its lower end is attached to another flat iron plate which slides up and down, guided by the sides of the arch, when the screw is turned. A stout, cross-handle is fixed on the upper part of the screw, by means of which it is turned. The use of the press is to squeeze together the pages of the letter-book which is placed between the lower fixed plate and the upper one which moves with the screw, and thus to obtain an impression or print of a newly-written letter which is placed between the pages of the book. Now, if you can imagine that the plates of such a press are taken

away, and replaced by metal dies, you will obtain some idea of what the coining-press was like. It was, of course, a larger machine than the copying-press, and the handles of the screw were heavily weighted, so that, when once they were put in movement, they swung round with their own weight, and brought down the upper die with a smart and powerful blow. The first coining-presses were worked by hand, but they are now put in motion by a steam-engine. Though the presses now in use are much more complicated than the early ones, they are in principle the same.

In days gone by, when coins were not so carefully made as they are now, it used to be a rather common practice for dishonest people to clip a little metal off the edges of the coins which passed through their hands. These clippings were probably sold to some equally dishonest goldsmith. You will think, perhaps, that so long as the coin could still be used, no great harm was done; but if I had time, I could show you that this clipping of coins was really a kind of robbery. It was at length put a stop to in a very simple way. If you look at the edge of a shilling you will see that it is grained. No one could clip the shilling without cutting off this graining; and once he had cut it off he could

not put it on again, and make the coin as neat and regular as it was before. Everyone to whom he offered the shilling would see that it had been clipped, and would refuse to take it. This graining or *milling*, as it is called, used to be put on by a very simple machine. I will try to illustrate its action. Place a penny on the table, and lay two flat rulers upon each side of it. Let the rulers be parallel, and touching the coin—squeezing the coin, in fact. Now, if you slide one of the rulers to and fro, you will be able to roll the penny from end to end between them. And you will see that if the edges of the rulers pressing against the penny were toothed, a *milling* might in this way be placed upon the edge of the coin. In the same way, too, an inscription might be impressed round the coin.

Nearly all our coins are now made at the Royal Mint in London. The metal is first melted, and a certain proportion of alloy is added to give the coin hardness. The alloy of gold and silver is chiefly copper, and that of copper is tin. The melted metal is cast into bars, and these are passed through rollers until they are reduced to the thickness of the coins which are to be made from them. From each sheet, or strip, of metal, a piece the size of a coin is cut out and

weighed, and if the weight is correct, the sheet is passed through a machine which cuts or stamps out round pieces the size of the required coins. These, having no pattern upon them, are called "blanks." Another machine raises the rim near the edge of the coin. The repeated squeezing which the metal has undergone makes it somewhat brittle, and to prevent the blanks from cracking under further pressure, they are annealed, that is to say, they are first heated, and then allowed to cool very slowly. After this they are washed in some weak acid, and dried in a revolting drum, which is full of sawdust. They are next carried to the coining-press, and placed in a tub, from which they are taken one by one by a pair of claws, and placed between the dies. When the claws slip their hold, a ring or collar falls round the blank, and holds it while the upper die comes down, and forces it upon the lower one. The inside of the ring is *milled*, and when the dies strike together, the blank flattens out a little, and takes the impression of the milling. When the upper die rises again, a spring lifts the collar off the coin, and the claws, bringing another blank, knock the coin aside. It is now finished, and, after being weighed and tested, it is ready for use. If it is found defective in any way, it is

returned to the melting-pot to be made anew.

The dies of a coining-press are made of steel. They are cut by a special workman, who is guided by an artist's designs. The steel is kept as soft as possible until the die is cut, when it is hardened. This first die is not used for stamping the coins, but other dies are made from it. These are used in the press, and in course of time they wear out or break. The original die is always kept as a model, so that however many coins are made they are all alike.

HOW EXPLOSIVES ARE MADE.

GUNPOWDER, GUN-COTTON, DYNAMITE.

WHEN we were considering how coal-gas is made, we found that heat and air, or rather oxygen, were necessary to make the coal burn ; and that when air was abundantly supplied by the use of bellows, the coal burned much faster than it did when simply shovelled in a heap upon the fire and left to burn without any further care. If we sprinkle a little coal-dust upon the fire, it blazes up so quickly as almost to burn up with a flash. It takes fire almost instantly, because each particle of coal is surrounded by air, and so receives the necessary heat and oxygen the moment it touches the fire. If the coal-dust were still finer, and if it were dispersed in the air like the dust which we see floating in the light of a sunbeam, it would sometimes be possible to set it on fire with a small light, and this would occur so

quickly and violently as to cause an explosion. Many strange explosions have occurred in corn mills and other works, where there is much dust raised. These can only be explained as dust explosions, resulting from the quick firing of small particles of dust, each of which is surrounded by air, and ready to take fire in a moment. And it is possible that some of the explosions which take place in coal-mines are explosions of coal-dust rather than coal-gas.

But perhaps you will ask why the quick burning of dust, or anything else, should produce not merely a fire or flash, but also a violent explosion, breaking down all before it. When coal burns, it unites with the oxygen of the air, and produces various gases which take up far more space than the coal itself. So long as the burning takes place gently, these gases find their way up the chimney, and escape quietly. But when the burning is accomplished in a moment, so much gas is produced, that the ordinary escapes are not sufficient, and such is the force of the changes started by the heat, that the expanding gases break down all manner of obstacles in their haste to be free.

There are some mixtures and compounds which always burn with an explosion. The oldest and best-known of these explosives is

gunpowder. It is a mixture of nitre or saltpetre, charcoal, and sulphur, in slightly varying proportions, according to the use to which the gunpowder is to be put. The gunpowder used for military purposes contains usually 75 parts of nitre, 15 of charcoal, and 10 of sulphur in every hundred parts of the powder. The ingredients are ground to dust, carefully mixed, and ground together in a mill, and at the same time sprinkled with water. The mixture is then pressed with great force into a solid cake, which is known as "press-cake." This "cake" is afterwards broken up into large or fine grains, according to the kind of gunpowder which is required. Finally, the gunpowder is rolled in a whirling drum to give the grains a polish and make them hard.

Though all gunpowder explodes, the explosion is quicker when the grains are small, and slower when they are large. This is not because the air reaches the smaller grains better, but because the heat acts upon them more quickly. Gunpowder carries its own stores of oxygen in the nitre, and does not require air in order to burn. When a light is applied to it, the nitre is set on fire, and as it burns it gives off a great deal of oxygen and sufficient heat to set the charcoal and sulphur on fire, the oxygen from the nitre

feeding them. Hot gases of various kinds are produced, and expand with a violent explosion. The quickness of the explosion is regulated by the size of the grains, and for reasons which it would take up too much space to explain, the grains of gunpowder used in our heaviest cannon have sometimes weighed half-a-pound each.

At one time gunpowder was the only explosive known, but now there are many others in use, and still more known to science. I will attempt to tell you something which you may understand about two of them—gun-cotton and dynamite.

If you have learned a little of practical chemistry, you will know that nitric acid is a clear, fuming liquid, which stains the skin when it touches it. Gun-cotton is made by steeping cotton-wool in nitric acid, or more usually a mixture of nitric acid and sulphuric acid. Upon being taken out of its bath, the cotton is washed until all traces of acid are removed, and it is then reduced to a pulp very similar to the paper-pulp from which paper is made. In this state it may be pressed into blocks of any required shape, which, after being dried, are ready for use.

If a light be applied to a block of dry gun-cotton, it burns quickly, but it does not explode. In order to explode it, we must

fire it by means of a little explosion near it. When that is done, the smaller explosion communicates its violence, as it were, to the gun-cotton, and the latter explodes with far more violence than the same weight of gunpowder. Strange to say, wet gun-cotton, which will not burn at all, can be exploded, or rather, detonated, almost as readily as dry gun-cotton. This explosive is therefore usually stored in a wet state, and there is little danger to be feared unless an explosion of dry gun-cotton should occur in the vicinity of the stores. A charge of gun-cotton for heavy work is usually made up of a body of wet gun-cotton, a small primer of dry gun-cotton, and a detonator, which may be a small charge of fulminate of mercury. The detonator is exploded, either by a light, an electric spark, or a spark produced by percussion or friction. The explosion of the detonator causes the detonation of the dry gun-cotton which surrounds, and this in its turn causes the explosion of the wet gun-cotton. Such a charge may be exploded under water as easily as on land, if only the detonator and primer be wrapped in waterproof cloth to keep them dry. Torpedoes are generally charged with gun-cotton.

If nitric acid be mixed with glycerine, and suitably washed, a liquid explosive resembling

glycerine in appearance, and known as nitro-glycerine, is formed. This liquid is detonated in the same way as gun-cotton, and explodes with a violence which is estimated to be four or five times greater than that produced by the same weight of gun-powder. As an explosive in the form of a liquid is very inconvenient for use, various experimenters tried to work nitro-glycerine up into some other form. A Swedish chemist, Nobel, found a spongy kind of clay which he impregnated with nitro-glycerine. The clay steeped in nitro-glycerine exploded like the nitro-glycerine itself, but with not quite so much force; but it had the great advantage of taking any shape which might be required. It could be pressed into holes in rocks or coal, and it could be made into cartridges. Clay thus soaked with nitro-glycerine is known as dynamite, and it is largely used in quarries and coalmines for breaking up the rocks and coal.

Many other explosives which bear strange names are very little different in composition and use from gun-cotton or dynamite.

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